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January 1995

US Army Corps of Engineers
Waterways Experiment Station

An Analysis of Freshwater Mussels (Unionidae) in the Upper Ohio River Near Huntington, West Virginia: 1993 Studies

by Andrew C. Miller, Barry S. Payne

Approved For Public Release; Distribution Is Unlimited

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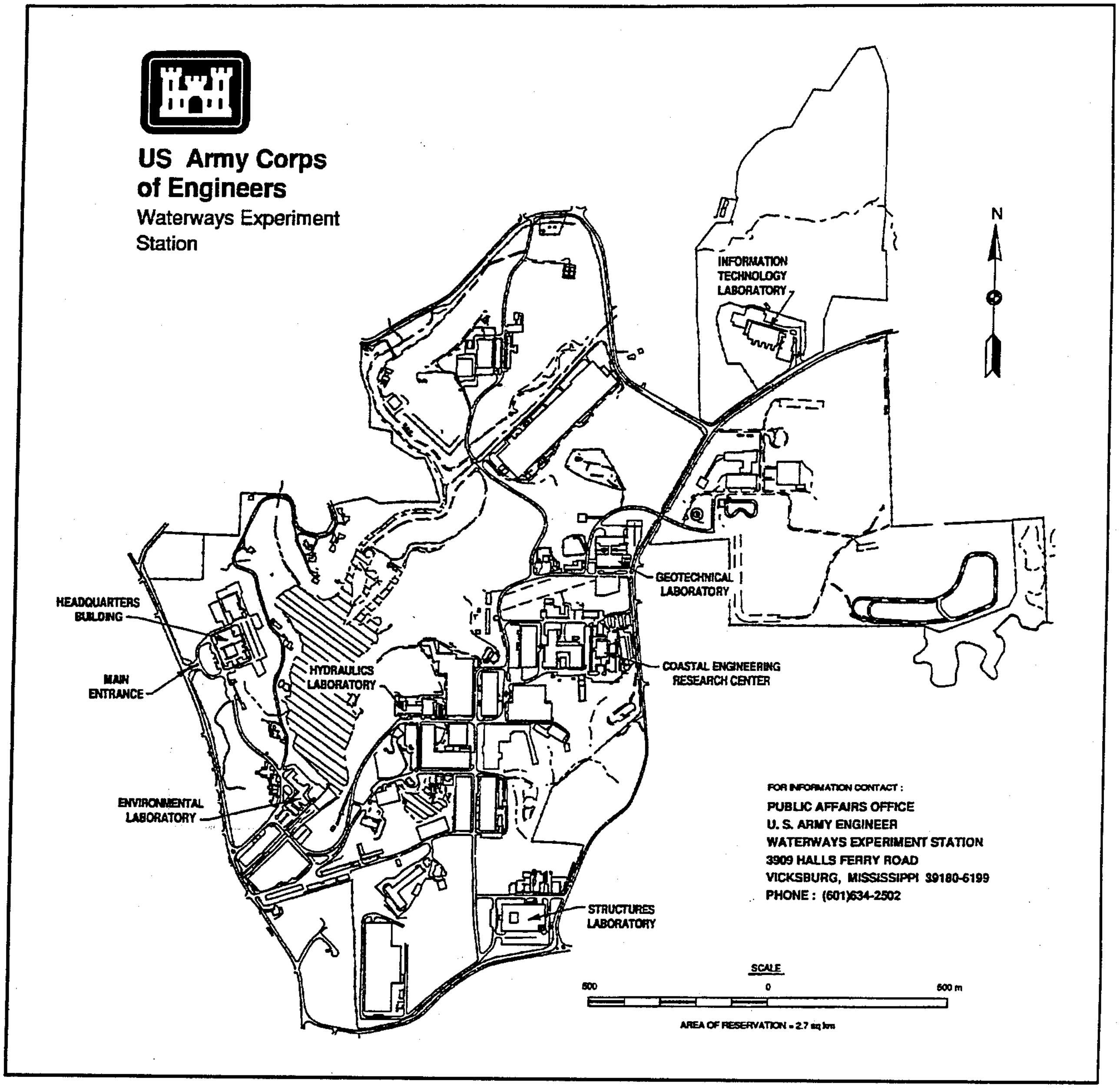

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Preface

The work reported herein was conducted by the U.S. Army Engineer Waterways Experiment Station (WES) in July 1993 for the U.S. Army Engineer District, Huntington, Huntington, WV. The purpose was to use qualitative and quantitative methods to collect freshwater mussels (Unionidae) from known mussel beds in a reach of the Ohio River near Huntington. Data on density, size demography of dominant populations, species diversity, and community composition will be used to analyze the environmental effects of water resource developments along the upper Ohio River.

Divers were Larry Neill, Kevin Chalk, Robert T. James, Jeff Montgomery, and Pat Hjelm from the Tennessee Valley Authority (TVA). Assistance in the field and advice on location of sampling sites were provided by Mr. Bill Tolin, U.S. Fish and Wildlife Service, and Mr. Barry Passmore, Huntington District. Travis Whiting assisted in the field. Ms. Deborah Shafer, WES, was the Diving Inspector for this work. Mr. Barry Passmore monitored the contract with WES. Ms. Eric Hubertz and Mr. David Felder processed mussels and *Corbicula fluminea* in the laboratory. Figures were prepared by Ms. Sarah Wilkerson, Mississippi College, and tables were prepared by Ms. Geralline Wilkerson, Hinds Community College.

During the conduct of this study, Dr. John Harrison was Director, Environmental Laboratory (EL), WES; Dr. C. J. Kirby was Chief, Environmental Resources Division, EL; and Dr. E. Theriot, was Chief, Aquatic Habitat Group, EL. Safety equipment and foul weather gear were provided by TVA. Authors of this report were Drs. Andrew C. Miller and Barry S. Payne, WES. Design of the study and conduct of all related activities in the field and laboratory were the sole responsibility of Drs. Miller and Payne.

At the time of publication of this report, Dr. Robert W. Whalin was the Director of WES. COL Bruce K. Howard, EN, was the Commander.

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Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
feet	0.3048	meters
miles (U.S. nautical)	1.852	kilometers
miles (U.S. statute)	1.609347	kilometers
square miles	2,589,998.0	square meters

1 Introduction

Background

In 1987 a conference on long-term studies in ecology was held at the Institute of Ecosystem Studies, New York Botanical Garden, New York. The goals of this conference were to (a) identify the roles of long-term ecological studies, (b) identify options for the study of long-term ecological phenomena, (c) evaluate strengths and weaknesses of various study approaches, (d) provide and clarify criteria for the most efficient and appropriate approaches to the study of long-term phenomena, and (e) examine how all approaches should be integrated to maximize understanding of long-term phenomena (Likens 1987). Ecological phenomena particularly amenable to long-term studies included: slow processes, rare events or episodic phenomena, processes with high variability, subtle processes, and complex phenomena (Likens et al. 1983, Strayer et al. 1986, as cited by Franklin 1987).

Freshwater mussels are long-lived (30 or more years in some species), rely on particulate organic matter for nutrition, and because they are relatively nonmotile, are unable to change their surroundings if conditions become unsuitable. Their habitat is affected by local and upriver changes in climate, season, land use, edaphic conditions, and water level. Habitat conditions are also affected by source and nonsource pollution, commodity movement, and commercial developments in the watershed. It is clear that man-made and natural disturbances in large rivers are long-term, complex, and often subtle and episodic. The characteristics of freshwater mussels can make them susceptible to these disturbances. Thus, these organisms, and their habitats, are particularly appropriate for long-term ecological studies.

The biological consequences of man-made and natural disturbances to habitat (specific physical and chemical conditions) can be measured on organisms held in the laboratory. However, caution must be used when extrapolating results of laboratory experiments to the field (Payne and Miller 1987). Physiological responses that occur in a laboratory often do not take place under natural conditions. Planners and biologists should evaluate the effects of natural and man-made disturbances on naturally

occurring populations rather than organisms held in the laboratory. Field studies are the best means of understanding effects of physical disturbances on naturally occurring populations. Studies can be designed to evaluate physical effects of water resource development on recruitment, rate of growth, density, species richness, and diversity. These parameters provide the most useful measures of the overall health and ultimate survival of a mussel community. Long-term studies on freshwater mussels in large rivers should not be discounted as "mere monitoring" (Taylor 1987). Instead, they provide an opportunity to investigate the effects of complex, episodic events on a resource with ecological, economic, and cultural value.

Purpose and Scope

The purpose of this report is to characterize important biotic variables (mussel density, evidence of recent recruitment, community structure, and spatial distribution) at mussel beds downriver of the Robert C. Byrd Lock and Dam in the Ohio River, WV. Results will be used by personnel of the U.S. Army Engineer District, Huntington, to evaluate the effects of water resource developments on freshwater mussels. In addition, these data will provide a baseline for evaluating the effects of introduction and spread of the exotic zebra mussel (*Dreissena polymorpha*) on native freshwater mussels.

2 Study Area and Methods

Study Area

The Ohio River originates in Pittsburgh, PA, at the confluence of the Allegheny and Monongahela Rivers. It flows 981 miles[1] to the northwest and then the southwest before it joins the Mississippi River near Cairo, IL. The river drains 203,900 square miles and falls 450 ft before it joins the lower Mississippi River.

For this project, study sites were located in the upper Ohio River (UOR) between river miles (RM) 292.0 and 284 (Table 1, Figures 1-4). Quantitative methods were used to collect bivalves at RM 292.0, 289.9, 287.2, and 284.0. Qualitative methods were used to collect mussels at RM 292.0, 289.9, 288.8, 287.2, and 284.0 (Table 1, Figures 2 and 3). The majority of samples were collected about 200 ft from shore in water between 12 and 25 ft deep.

At all mussel beds studied, substratum consisted of stable sand mixed with medium-sized to large gravel. Particles less than 12.7 mm in diameter were approximately equally abundant at all four mussel beds. Particle sizes between 12.7 and 34.0 mm were about twice as common at the upriver portion of the study area (RM 284.0) than at the three mussel beds located farther downriver. Substratum at the upriver reach of the study area (RM 284.0) had a comparatively lower percentage of large-sized particles (>34.0 mm) than substratum at the other mussel beds (Figure 4).

1 A table of factors for converting non-SI units of measurement to SI units is presented on page x.

Table 1
Location and Number of Samples Collected Using Qualitative and Quantitative Methods in the Upper Ohio River, July 1993

Date	River Mile	Bank[1]	Distance to shore, ft	Water Depth, ft	Qualitative Samples: Site No.	Qualitative Samples: Total No. of Samples	Qualitative Samples: No. of Sites	Quantitative Samples: No. of Subsites	Quantitative Samples: Total No. of Samples
14 Jul 93	292.0	RDB	200	12-25	1	12	1	2	20
14 Jul 93	289.9	RDB	200	12-25	2	12	1	2	20
15 Jul 93	288.8	LDB	200	12-25	3	5	1	0	0
15 Jul 93	289.9	RDB	200	12-25	4-6	36	3	0	0
15 Jul 93	287.2	LDB	200	12-25	7-12	72	6	0	0
16 Jul 93	287.2	LDB	200	12-25		0		3	20
16 Jul 93	287.2	LDB	200	12-25		0		1	10
17 Jul 93	284.0	LDB	200	12-25	20-25	72	6	4	28
18 Jul 93	287.2	LDB	200	12-25	13-19	84	7	2	20
Total						293	25	14	118

[1]RDB = right descending bank, LDB = left descending bank.

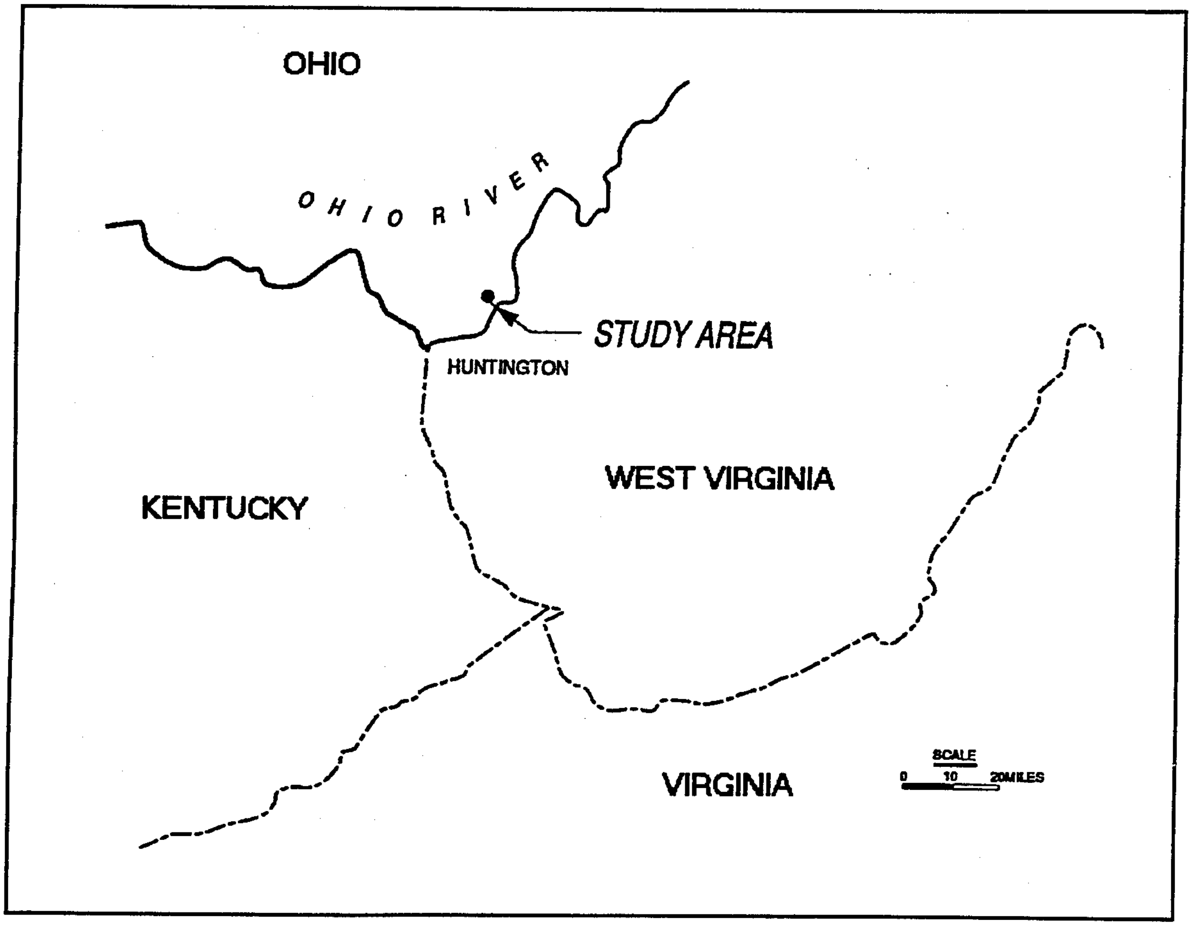


Figure 1. Study area

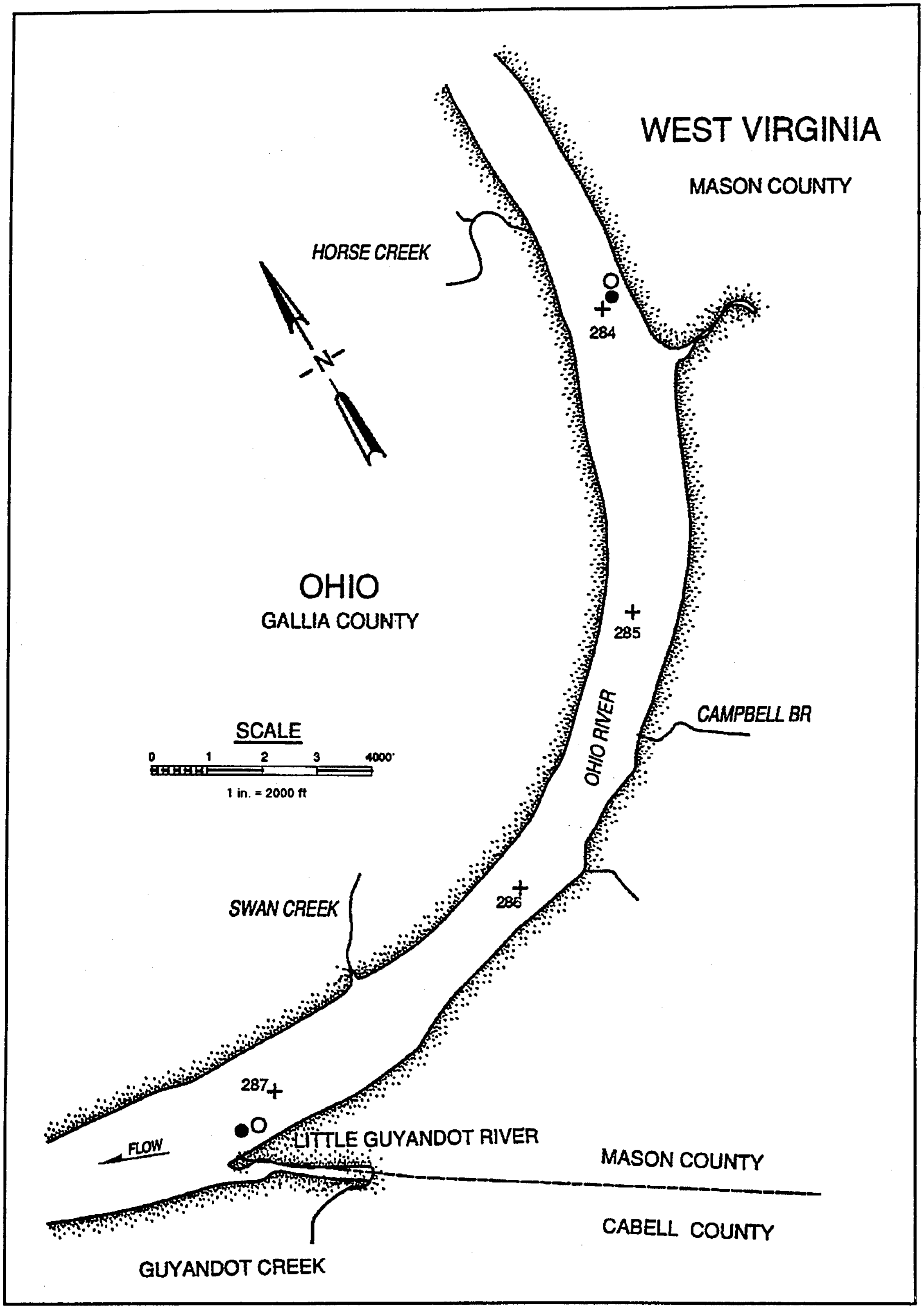


Figure 2. Quantitative (solid circles) and qualitative (open circles) sample sites between RM 287 and 284

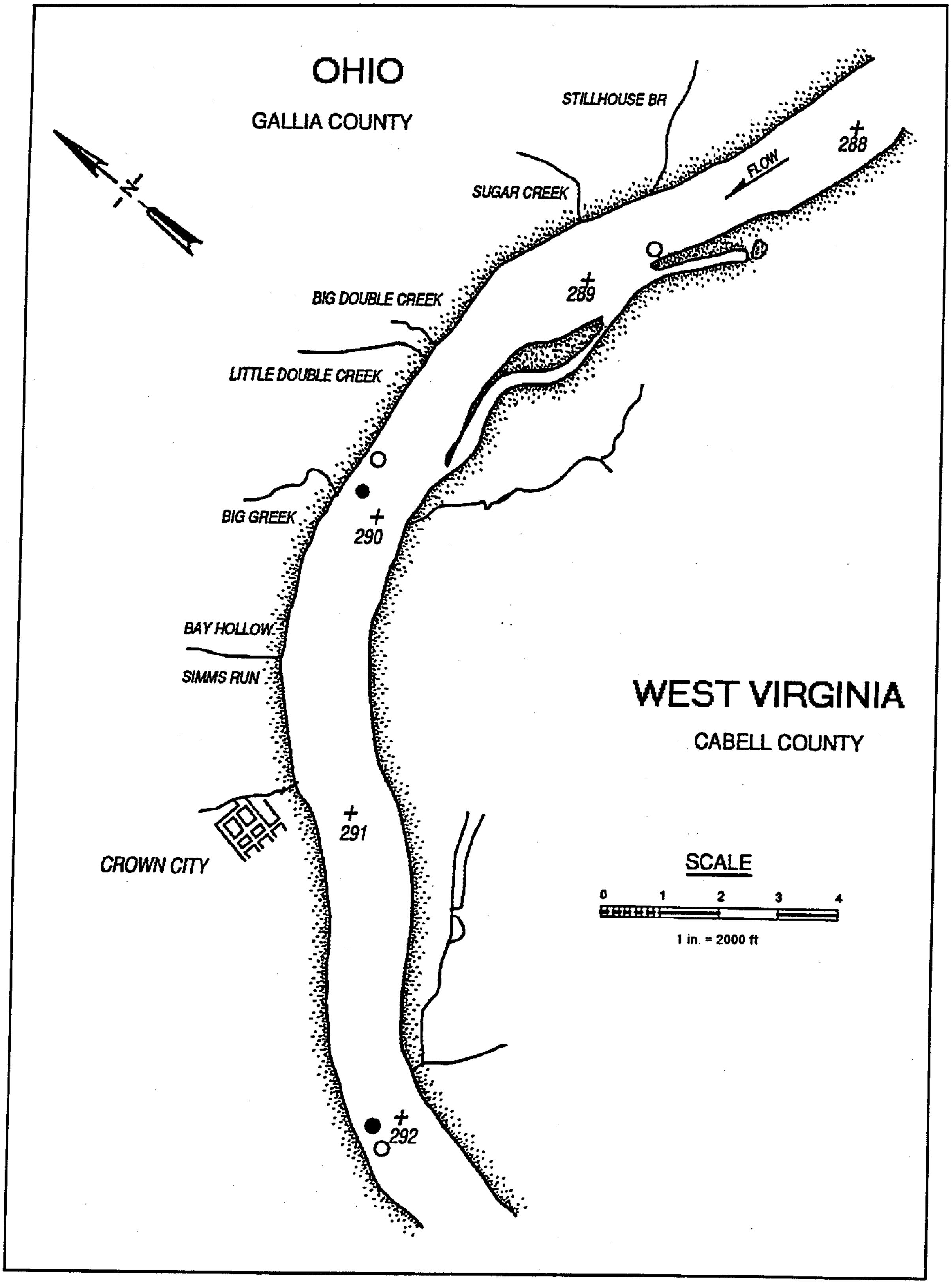


Figure 3. Quantitative (solid circles) and qualitative (open circles) sample sites between RM 292 and 288

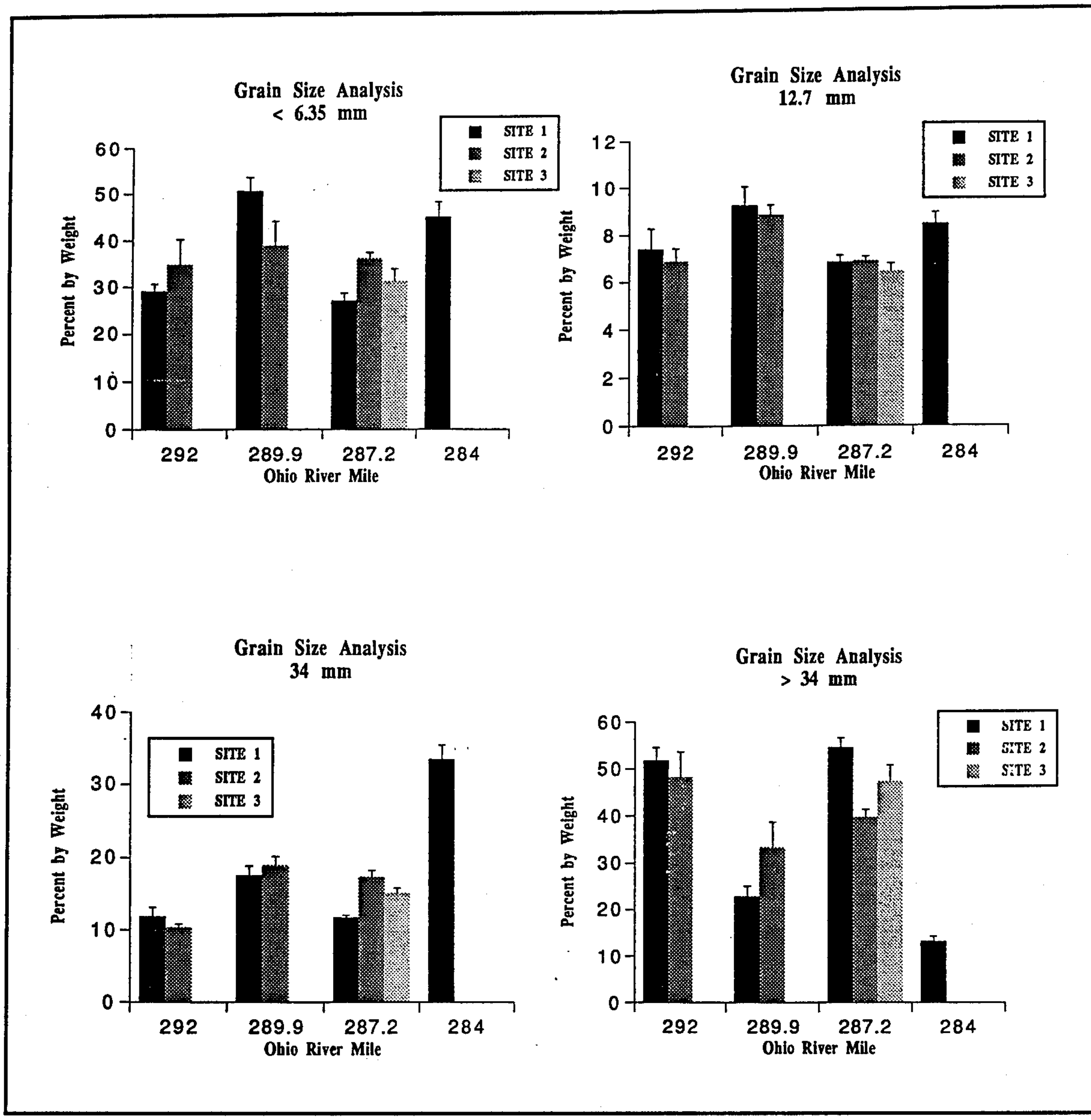


Figure 4. Grain size analysis for four locations on the upper Ohio River where quantitative samples were collected

Methods

Preliminary reconnaissance

All underwater work was accomplished by a dive crew equipped with surface-supplied air and communication equipment. Before intensive sampling was initiated, a single diver conducted a preliminary reconnaissance of the immediate area. The diver obtained information on substratum type, water velocity, and presence of mussels. Qualitative sampling was initiated if the substratum appeared stable and if there was moderate to high mussel density (i.e., at least 3 to 5 individuals/sq m).

Qualitative mussel samples

The majority of the qualitative samples were obtained by having two divers collect simultaneously. Each diver placed a specific number of live mussels in each of six nylon bags; five mussels were placed in three bags and twenty were placed in each of the other nine bags. At each site 12 samples and approximately 200 individuals were collected. Divers were instructed to obtain mussels without bias toward size or type. They attempted to exclude the Asiatic clam, *Corbicula fluminea*. If *C. fluminea* was inadvertently collected, it was later eliminated. A total of 118 qualitative samples (bags of mussels) were taken from 29 sites on the four mussel beds (Table 1). Typically, 12 samples were taken at each site; however at RM 288.8 only 5 samples were taken. Fewer samples were taken at this mussel bed since densities were extremely low.

All mussels were brought to the surface, counted, and identified. Data were recorded on standard data sheets and returned to the laboratory for analysis and plotting. Shells of voucher specimens for each species were placed in plastic zipper lock bags and labeled with high rag content paper. Mussels not needed for voucher were returned to the river. Methods for sampling mussels were based on techniques described in Coker (1919), Brice and Lewis (1979), Miller and Nelson (1983), Isom and Gooch (1986), Kovalak, Dennis, and Bates (1986), Miller and Payne (1988), and Miller et al. (1993). Mussel identification was based on taxonomic keys and descriptive information in Murray and Leonard (1962), Parmalee (1967), Starrett (1971), and Burch (1975). Taxonomy is consistent with Turgeon et al. (1988).

Quantitative mussel samples

Quantitative samples (that included unionids as well as *C. fluminea*) were obtained at RM 292.0, 289.9, 287.2, and 284.0 in the UOR. At each mussel bed, bivalves were collected at each of two to five sites that were separated by 5 to 10 m. At each site, 6 to 10 quadrats (0.25 sq m) were positioned approximately 1 m apart for collecting. A diver excavated all sand, gravel, shells, and live bivalves to a depth of 10 to 15 cm. Material was sent to the surface in a 20-L bucket and transported to shore. Sediment was screened through a sieve series. All live mussels and *C. fluminea* removed from samples were placed in 4-L zipper lock bags. Each bivalve was then identified and total shell length (SL) measured to the nearest 0.1 mm with a digital caliper. If time permitted, mussels were measured in the field and returned to the river unharmed. All endangered or very uncommon species were returned to the river after measuring. Selected samples were preserved in 10 percent buffered formalin and returned to the laboratory for identification and measurement. All *C. fluminea* were preserved and processed in the laboratory.

Grain size analysis

Sediments from the quantitative samples on each wash screen were weighed on a top loading balance in the field. Mesh sizes of screens were: 34.0, 12.7, and 6.35 mm. The sediments on each screen (excluding the mass of bivalves which were treated separately) were weighed in the field.

Data analysis

Species diversity was determined with the following formula:

$$H' = -p_j \log p_j$$

where p_j is the proportion of the population that is of the jth species (Shannon and Weaver 1949). Evenness was calculated with the modified Hill's ratio (Ludwig and Reynolds 1988). All calculations were made with programs written in BASIC or SAS (Statistical Analytical System) on a personal computer. Discussion of statistical procedures that were used can be found in Green (1979) and Hurlbert (1984). Species area curves and dominance-diversity curves were constructed from qualitative and quantitative biological data. More information on methods used for this survey can be found in McNaughton and Wolf (1973), Isom and Gooch (1986), Kovalak, Dennis, and Bates (1986), Hughes (1986), Miller and Payne (1988), and Miller et al. (1993).

3 The Bivalve Community

Community Characteristics

Qualitative samples

A total of 4,700 individuals and 24 species of mussels were collected at five locations in the study area using qualitative methods (Tables 2 and 3). The fauna was dominated by two thick-shelled species (*Elliptio crassidens* and *Quadrula pustulosa pustulosa*), which comprised 54.7 and 18.3 percent of the fauna collected in qualitative samples, respectively. *Elliptio crassidens* was taken in all qualitative samples at each location and comprised from 15.8 to 63.7 percent of the fauna (Table 3). Eight species comprised 1 to 8 percent of the fauna, and 14 species each comprised less than 1 percent of the fauna. The majority of these mussels were thick or moderately thick species; thin-shelled species (*Lampsilis ovata* and *Leptodea fragilis*) were uncommon and comprised 0.40 and 0.02 percent of the mussels, respectively. One specimen of *Lampsilis abrupta*, listed as endangered by the U.S. Fish and Wildlife Service (1991), was collected at RM 287.2. The total number of species collected at these five locations ranged from 6 to 19, and species diversity ranged from 1.35 to 1.76. Beds at RM 292.0, 289.9, 287.2, and 284.0 were characterized by high species richness and moderate density. Low density populations were found at the bed at RM 288.7.

The collection rate for Unionidae ranged from 0.2 to 5.9 individuals/diver min (mean = 2.9 individuals/diver min) (Table 5). The highest rate was obtained at RM 287.2, and the lowest rate was obtained at RM 288.8. Sampling was stopped at this latter site because of low density.

A plot of percent species abundance (Figure 5) and percent occurrence of each species (Figure 6) versus species rank provides a graphical depiction of the summary columns of Tables 3 and 4. For comparison, data from the 1992 survey have been included (Miller and Payne 1994). Percent abundances of abundant and common species were similar between the two study years. The survey conducted in 1993 was more intense than that of 1992 (only 1,477 individuals were collected using qualitative

Table 2
Freshwater Mussels Collected Using Qualitative and Quantitative Methods in the Upper Ohio River, 1993

Species	Qualitative	Quantitative
Actinonaias ligamentina (Lamarck, 1819)	X	X
Amblema p. plicata (Say, 1817)	X	X
Ellipsaria lineolata (Rafinesque, 1820)	X	X
Elliptio crassidens (Lamarck, 1819)	X	X
Fusconaia ebena (I. Lea, 1831)	X	X
Fusconaia subrotunda (I. Lea, 1839)	X	
Lampsilis ovata (Say, 1817)	X	X
Leptodea fragilis (Rafinesque, 1820)	X	
Ligumia recta (Lamarck, 1819)	X	
Megalonaias nervosa (Rafinesque, 1820)	X	
Obliquaria reflexa (Rafinesque, 1820)	X	X
Plethobasus cyphyus (Rafinesque, 1820)	X	
Pleurobema cordatum (Rafinesque, 1820)	X	X
Pleurobema coccineum (Conrad, 1834)	X	
Potamilus alatus (Say, 1817)	X	X
Quadrula p. pustulosa (I. Lea, 1831)	X	X
Quadrula quadrula (Rafinesque, 1820)	X	X
Quadrula metanevra (Rafinesque, 1820)	X	X
Truncilla truncata (Rafinesque, 1820)		X
Lasmigonia costata (Rafinesque, 1820)	X	X
Fusconia flava (Rafinesque, 1820)	X	X
Quadrula nodulata (Rafinesque, 1820)	X	
Lasmigonia c. complanata (Barnes, 1823)	X	
Obovaria subrotunda (Rafinesque, 1820)	X	
Lampsilis abrupta (Say, 1831)	X	
Total species	24	16
Total individuals	4,700	191

methods in the previous year); hence, a greater number of species was collected. Regardless of the intensity of the survey, the unionid community can be characterized as evenly distributed with no clear dominants and spans three orders of magnitude.

The greater effort expended in 1993 yielded seven species that occurred in less than 1 percent of the samples (Table 4 and Figure 6). Samples from 1993 spanned two orders of magnitude whereas those from 1992 spanned only one order of magnitude.

The relationship between the cumulative number of individuals collected and the cumulative number of species collected illustrates the amount of effort required to collect very uncommon species. Data from

Table 3
Percent Species Abundance of Unionidae Collected in the Upper Ohio River Using Qualitative Methods, July 1993

Species	RM 292.0	RM 289.9	RM 288.7	RM 287.2	RM 284.0	Total
E. crassidens	42.06	42.24	15.79	63.70	46.81	54.70
Q. p. pustulosa	23.83	23.92	31.58	13.78	22.85	18.28
P. cordatum	5.61	6.49	0.00	9.23	3.91	7.23
Q. metanevra	8.41	8.02	21.05	2.60	9.09	5.47
A. ligamentina	0.93	2.54	0.00	2.28	5.78	3.13
A. p. plicata	2.80	4.33	15.79	1.72	1.70	2.26
F. ebena	0.47	2.16	0.00	2.00	0.85	1.66
Q. quadrula	2.80	2.93	0.00	0.56	2.89	1.64
M. nervosa	1.40	1.91	0.00	1.28	1.02	1.32
P. alatus	0.93	1.78	0.00	0.88	2.04	1.32
O. reflexa	0.47	1.53	0.00	0.40	1.36	0.83
L. recta	8.41	0.13	0.00	0.12	0.42	0.57
P. cyphyus	0.47	0.38	5.26	0.48	0.25	0.43
L. ovata	1.40	0.51	10.53	0.12	0.59	0.40
P. coccineum	0.00	0.76	0.00	0.36	0.08	0.34
F. subrotunda	0.00	0.00	0.00	0.16	0.08	0.11
E. lineolata	0.00	0.00	0.00	0.12	0.08	0.09
Q. nodulata	0.00	0.00	0.00	0.12	0.00	0.06
L. complanata	0.00	0.00	0.00	0.04	0.08	0.04
O. subrotunda	0.00	0.13	0.00	0.00	0.08	0.04
F. flava	0.00	0.00	0.00	0.04	0.00	0.02
L. abrupta	0.00	0.00	0.00	0.04	0.00	0.02
L. costata	0.00	0.13	0.00	0.00	0.00	0.02
L. fragilis	0.00	0.13	0.00	0.00	0.00	0.02
Total individuals	214	786	19	2,504	1,177	4,700
Total species	14	18	6	21	19	24
Species diversity (H')	1.76	1.83	1.67	1.35	1.7	1.59
Evenness	0.62	0.57	1.18	0.45	0.60	0.48

1992 and 1993 have been included for comparison (Figures 7 and 8), and the sampling locations have been ranked from highest river mile (farthest downriver) to lowest river mile (farthest upriver). Data from the two sampling years were very similar based on these species effort curves. In 1993, 16 species (80 percent of the collection) were found after slightly more than 400 individuals were collected at RM 292.2 (Figure 7). In 1992 at the same location, 16 species had been collected after 190 individuals were collected. In 1992, nearly 1,500 individuals were collected and 20 species were identified. In 1993, the first 1,500 individuals collected (when ranked by river mile) yielded 18 species, and after nearly 5,000 individuals had been collected, 24 species were identified (Figure 8).

Table 4
Percent Occurrence of Unionidae Collected in the Upper Ohio River Using Qualitative Sampling Methods, July 1993

Species	RM 292.0	RM 289.9	RM 288.7	RM 287.2	RM 284.0	Total
E. crassidens	83.33	95.83	40.00	67.98	100.00	97.27
Q. p. pustulosa	91.67	93.75	100.00	55.70	87.50	85.67
P. cordatum	66.67	54.17	0.00	46.49	43.06	58.36
Q. metanevra	83.33	64.58	60.00	21.49	73.61	49.83
A. ligamentina	8.33	35.42	0.00	20.18	59.72	36.52
A. p. plicata	33.33	52.08	60.00	14.04	22.22	27.30
F. ebena	8.33	20.83	0.00	16.67	13.89	20.14
Q. quadrula	41.67	37.50	0.00	4.82	37.50	20.82
M. nervosa	25.00	22.92	0.00	12.72	13.89	18.09
P. alatus	16.67	22.92	0.00	8.33	25.00	17.06
O. reflexa	8.33	22.92	0.00	2.63	18.06	10.58
P. cyphyus	8.33	6.25	20.00	3.95	4.17	5.80
L. ovata	25.00	8.33	40.00	1.32	8.33	6.14
P. coccineum	0.00	10.42	0.00	3.51	1.39	4.78
L. recta	8.33	2.08	0.00	1.32	6.94	3.41
F. subrotunda	0.00	0.00	0.00	1.75	1.39	1.71
E. lineolata	0.00	0.00	0.00	1.32	1.39	1.37
L. complanata	0.00	0.00	0.00	0.44	1.39	0.68
O. subrotunda	0.00	2.08	0.00	0.00	0.00	0.34
F. flava	0.00	0.00	0.00	0.44	0.00	0.34
L. abrupta	0.00	0.00	0.00	0.44	0.00	0.34
L. costata	0.00	2.08	0.00	0.00	0.00	0.34
Q. nodulata	0.00	0.00	0.00	0.44	0.00	0.34
L. fragilis	0.00	2.08	0.00	0.00	0.00	0.34
Total No. of samples	12	48	5	156	72	293

There were no specific trends with respect to river mile for abundance of common species (Figure 9). *Elliptio crassidens* was slightly more abundant at RM 287.2, and a higher percentage of *Q. metanevra* was collected at RM 292.0 than at the other locations. However, these minor differences in community composition were probably related to intersite variation rather than specific trends with respect to river mile.

Quantitative samples

A total of 191 individuals and 16 species were collected in the 118 quantitative samples taken at four locations in the UOR (Table 6). *Quadrula pustulosa pustulosa* and *E. crassidens* comprised 37.7 and 26.2 percent, respectively, of the Unionidae collected in quantitative samples (Table 6). Ten species comprised between 1 and 9 percent of the fauna,

Table 5
Total Mussels, Total Time Required to Collect, and Collection Rate Using Qualitative Methods in the Upper Ohio River, July 1993 (Collection Time Was Not Recorded for All Samples)

RM	Sample No.	Total Mussels	Total Time	Mussels/Min
289.9	2	217	227	0.96
288.8	3	19	93	0.20
289.9	4	194	123	1.58
289.9	5	193	150	1.29
289.9	6	182	114	1.60
287.2	7	184	115	1.60
287.2	8	189	205	0.92
287.2	9	190	105	1.81
287.2	10	193	61	3.16
287.2	11	194	57	3.40
287.2	12	194	36	5.39
287.2	13	194	37	5.24
287.2	14	194	46	4.22
287.2	15	194	41	4.73
287.2	16	194	39	4.97
287.2	17	194	85	2.28
287.2	18	194	57	3.40
287.2	19	194	33	5.88
284.0	20	188	136	1.38
284.0	21	195	103	1.89
284.0	22	198	77	2.57
284.0	23	198	61	3.25
284.0	24	197	63	3.13
284.0	25	201	44	4.57
Mean		186.8	87.8	2.9
Maximum		217	227	5.9
Minimum		19	33	0.2
Range		198	194	5.7

and four species comprised less than 1 percent of the fauna. Fewer species (16) were taken using quantitative rather than qualitative methods (25 species, Table 3). This was the result of the large number of individuals collected using qualitative methods (4,700) as compared with quantitative methods (191). Three species were found in more than 10 percent of all quantitative samples (*Q. p. pustulosa, E. crassidens*, and *Quadrula metanevra*, Table 7. Nine species occurred in 1 to 9 percent of the quantitative samples, and four species were found in less than 1 percent of the samples. Four species were taken only in one of the 118 quantitative samples collected at these mussel beds.

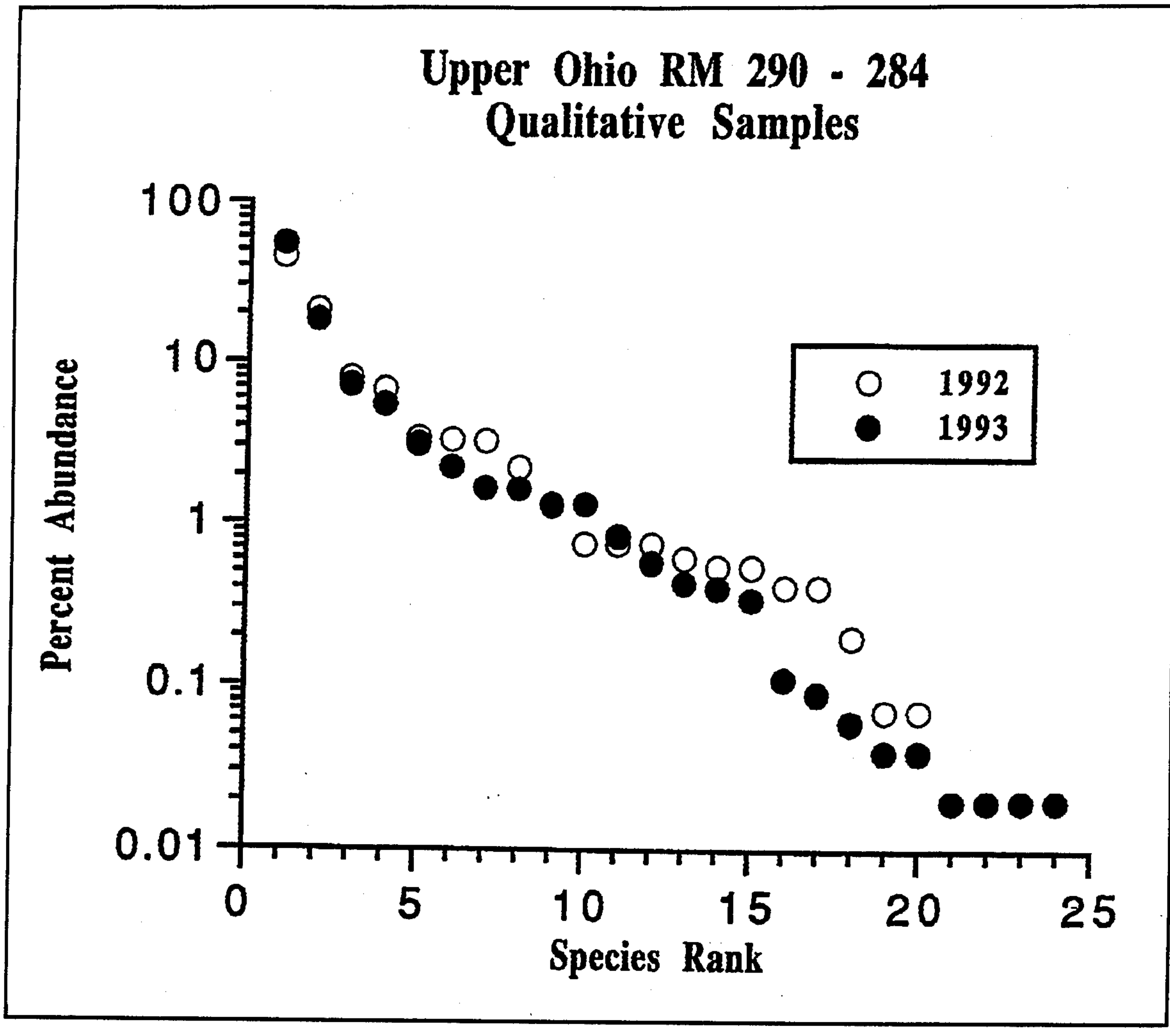


Figure 5. Relationship between percent abundance and species rank for mussels collected using qualitative methods, 1992 and 1993

Species richness, diversity, and evidence of recent recruitment

Species diversity ranged from 1.60 to 1.86 (overall species diversity was 1.89), and evenness ranged from 0.67 to 0.96 (overall was 0.61) (Table 6). This indicates a moderately diverse community without a clear dominant (i.e., no species comprised more than 70 percent of the community). Species diversity was slightly greater at RM 292 and 287 in 1993 as compared with 1993 and was slightly less at RM 284 in 1993 as compared with 1992 (Figure 10).

A quantitative indicator of recent recruitment is the percentage of individuals and species less than 30-mm total shell length. This will include all Unionidae less than 2 to 3 years old regardless of species. Evidence of recent recruitment is low in this reach of the UOR. Overall, 3.7 percent of the individuals collected using quantitative methods were less than this 30-mm total shell length. The percentage of species with representatives less than 30 mm in total shell length was 18.7 percent. When compared

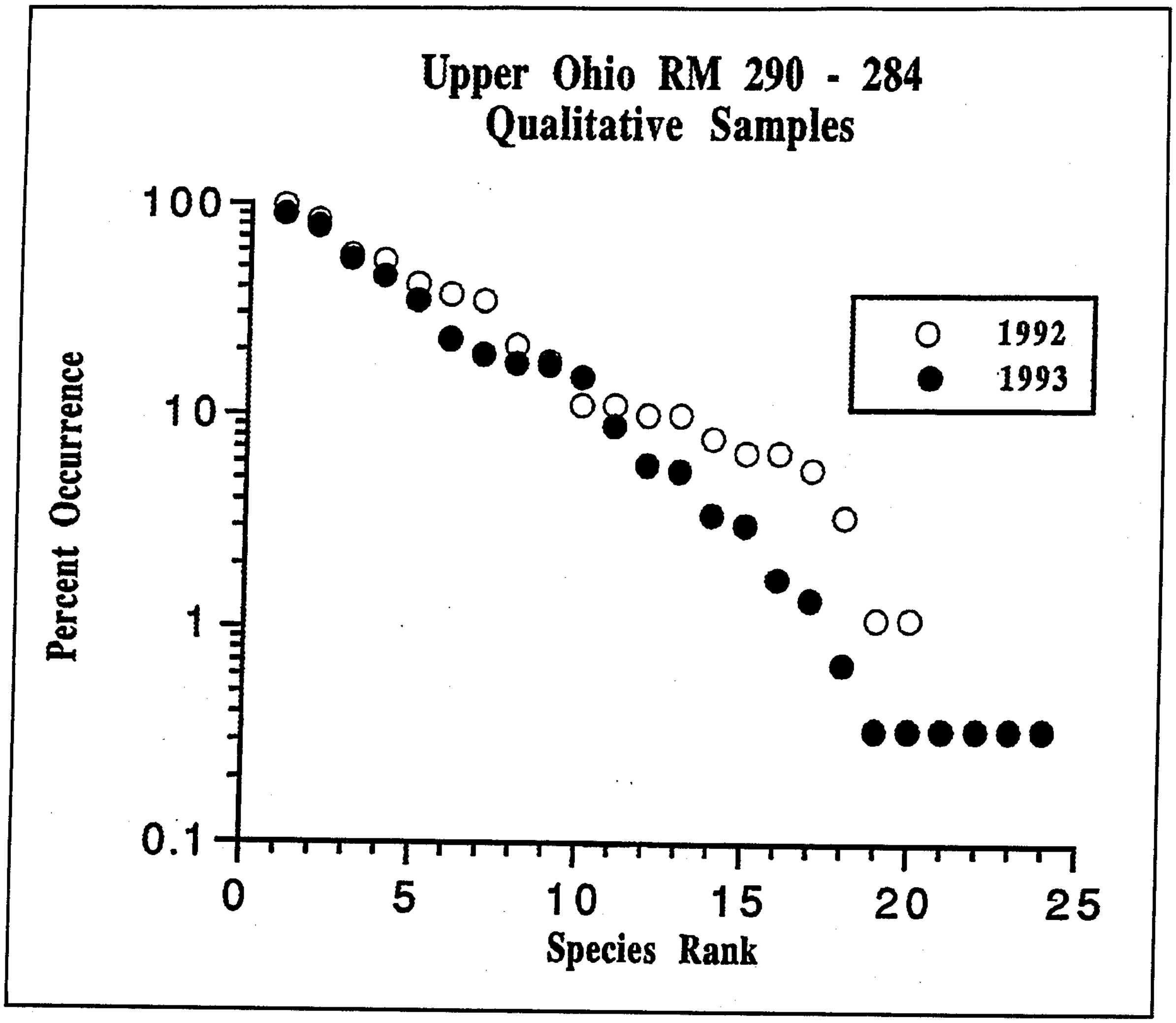


Figure 6. Relationship between percent occurrence and species rank for mussels collected using qualitative methods, 1992 and 1993

with 1992, evidence of recent recruitment had changed little at RM 287 (Figure 11). However, in contrast to 1992, no evidence of recent recruitment was found at RM 292 and RM 284 in 1993. *Quadrula pustulosa pustulosa* exhibits the greatest evidence of recent recruitment of all unionid species in this reach of the UOR. Percentage of individuals of this species less than 30 mm was 14.8 in 1992 and 6.9 in 1993. The only other species showing evidence of recent recruitment in 1992 was *Truncilla truncata* (3 percent). The only species besides *Q. p. pustulosa* showing evidence of recent recruitment in 1993 was *T. truncata* (one of two individuals) and *Obliquaria reflexa* (one of nine individuals).

As with the qualitative sampling (Figures 6 and 7), results of quantitative sampling characterized the community as evenly distributed, with no clear dominant (Figure 12). The species spanned two orders of magnitude and few differences between 1992 and 1993 were noted. Percent occurrence versus species rank was similar for 1992 and 1993 (Figure 13).

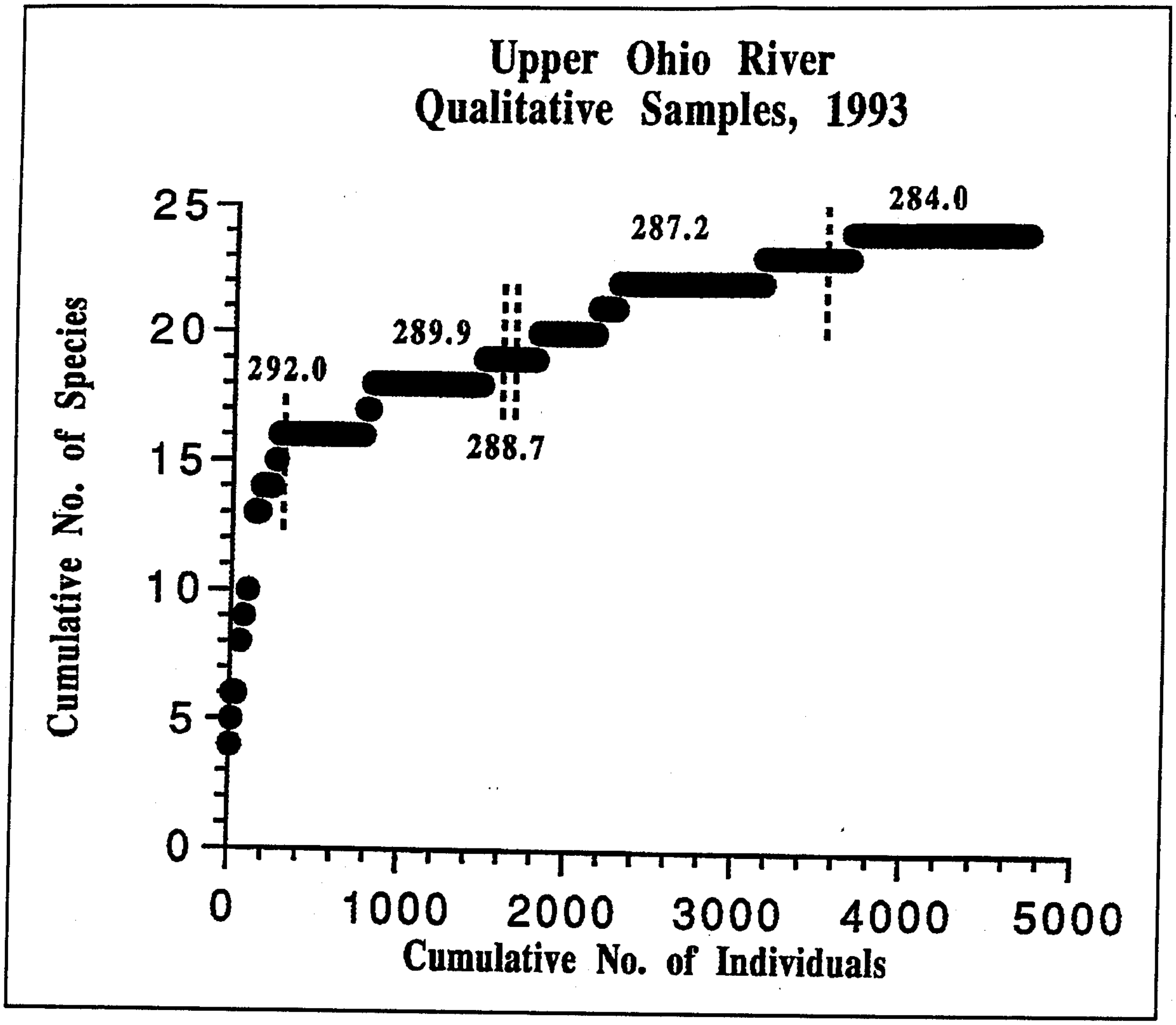


Figure 7. Relationship between cumulative number of individuals and cumulative number of species collected using qualitative methods, 1993

After approximately 190 individuals had been collected, 16 species had been collected using quantitative methods in 1993 (Figure 14). This is similar to 1992 when, after 60 individuals had been collected, 15 species had been identified (Figure 15). It should be apparent that the greater number of samples collected (and individuals processed) using qualitative methods provides an opportunity to collect uncommon species such as *L. abrupta* (compare Figures 14 and 15 with Figures 7 and 8).

Mean density

Total mean density (individuals per square meter) of *C. fluminea* was significantly higher at RM 284.0, the mussel bed located farthest upriver, than at RM 292.0, the most downriver mussel bed (821.1 ± 104.2 SE as compared with 65.6 ± 7.1) (Table 8, Figure 16). Biomass (grams per square meter) followed the same trend and was also significantly higher at the upriver as compared with the downriver mussel bed. Mean biomass

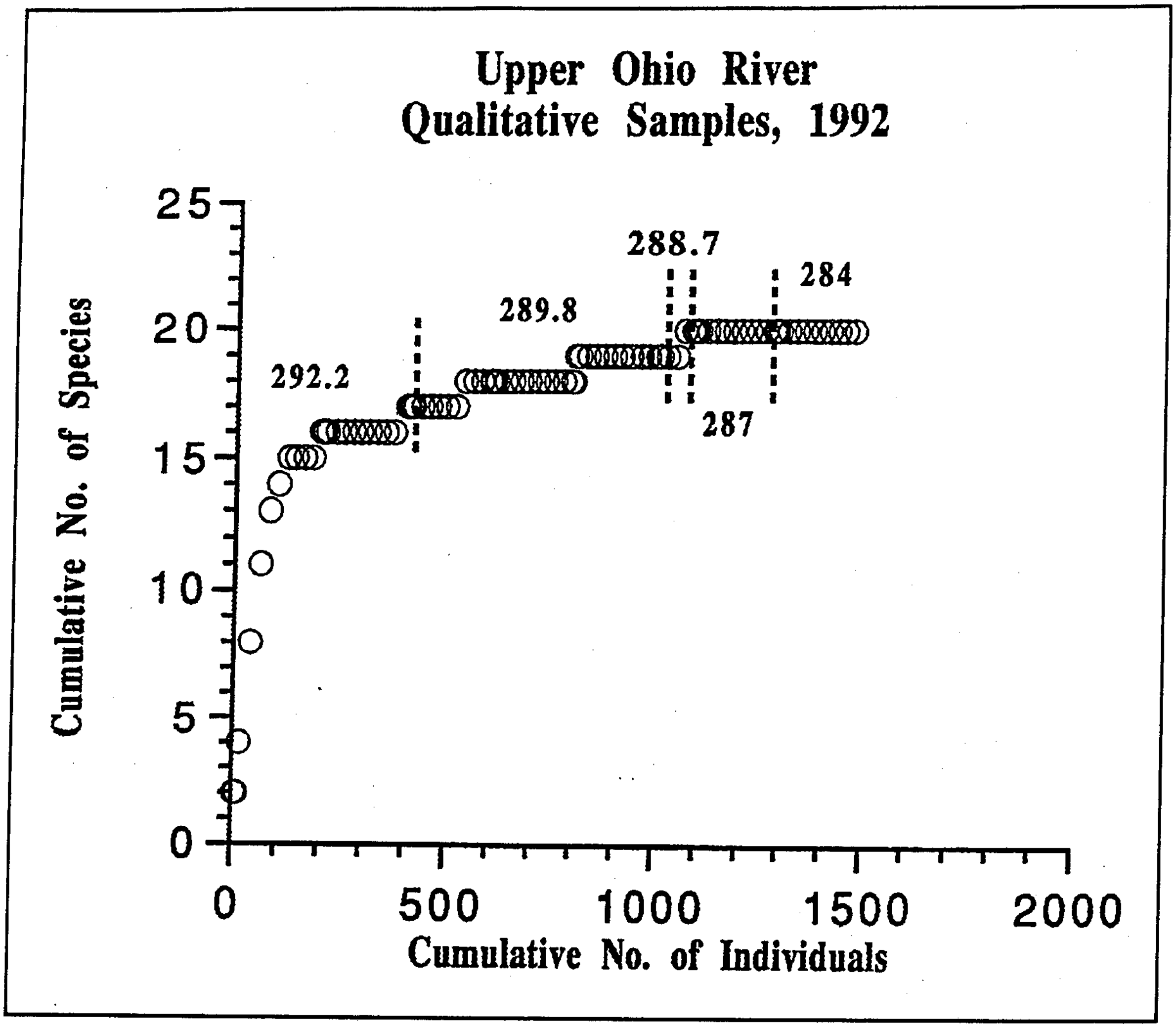


Figure 8. Relationship between cumulative number of individuals and cumulative number of species collected using qualitative methods, 1992

was 2,935.9 (±314.0) at RM 284 and 230.1 (±24.1) at RM 292, the most downriver location. There was no significant difference ($p < 0.05$) within site variation in density or biomass of *C. fluminea* at RM 292.0 or RM 289.9 (Table 9). However, there was significant within site variation in density and biomass at the mussel beds located at RM 287.2 and RM 284.0.

Total mean density of Unionidae ranged from a high of 13.4 (±2.0 SE) at the bed at RM 292.0 to a low of 3.6 (±0.7) at RM 284.0, the most upriver mussel bed (Table 8, Figure 17). Total mean density of Unionidae was significantly greater at RM 292.0 than at the other four mussel beds surveyed (Table 8). Within-bed variation was low during this survey year; F-values for within-subsite analysis ranged from 0.08 to 0.64 ($p > 0.46$, Table 10). Mean biomass ranged from a high of 2,119.7 (±294.1) at RM 292 to a low of 414.4 (±103.9) at RM 284.0. As with total density, mean biomass was significantly greater at RM 292.0 than at RM 284.0 ($p > 0.0001$).

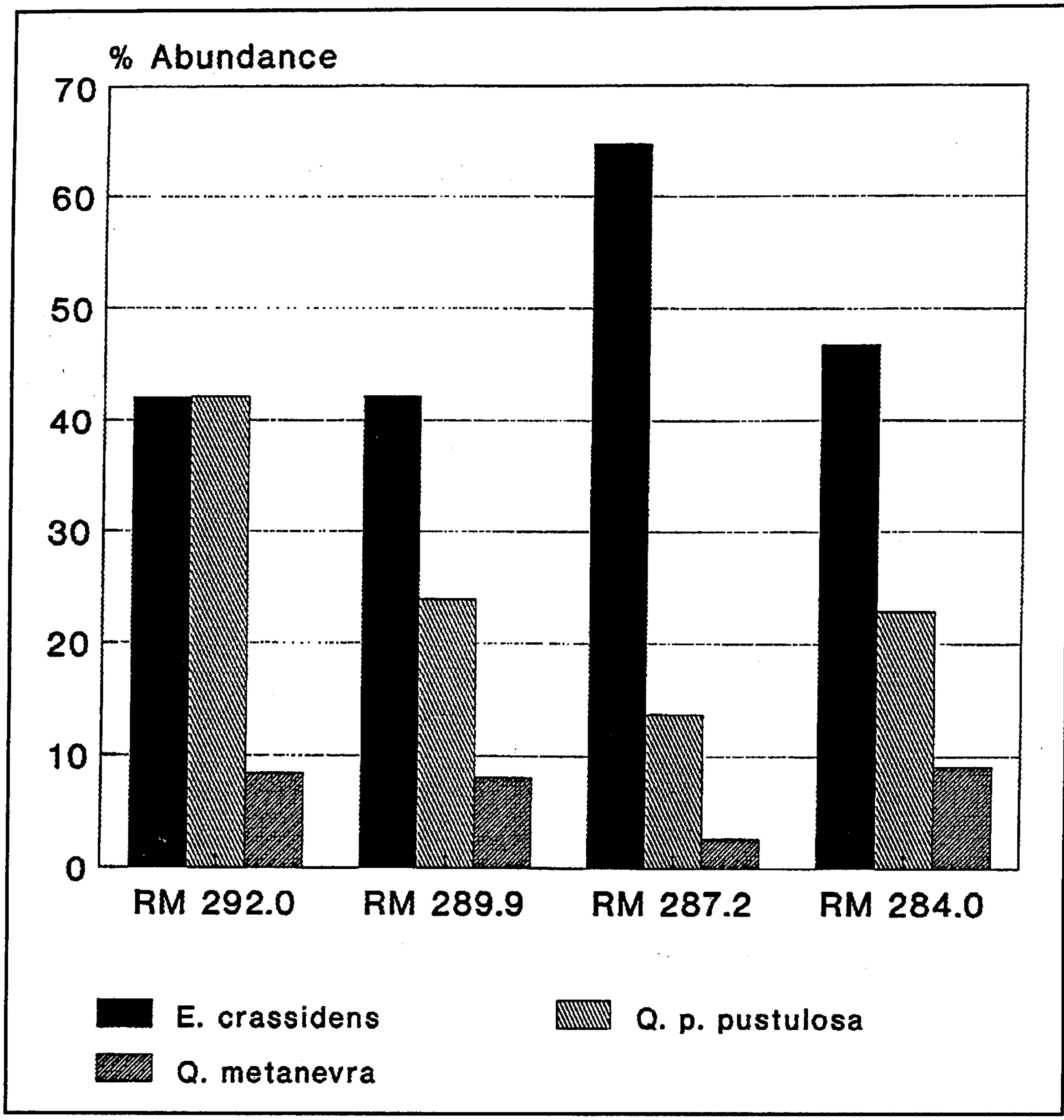


Figure 9. Percent abundance for *E. crassidens*, *Q. p. pustulosa*, and *Q. metanevra* collected using qualitative methods at four locations, 1993

There was a substantial increase in density of intermediate-sized (17.0 to 24.9 mm) *C. fluminea* moving upriver in the study area (Figure 18). Asian clams less than 17.0 mm were uncommon and exhibited no specific trends with respect to river mile.

Table 6
Percent Species Abundance of Unionidae Collected in the Upper Ohio River Using Quantitative Sampling Methods, July 1993

Species	RM 292.0	RM 289.9	RM 287.2	RM 284.0	Total
Q. p. pustulosa	35.82	36.36	40.26	36.00	37.70
E. crassidens	28.36	22.73	24.68	28.00	26.18
Q. metanevra	7.46	22.73	6.49	8.00	8.90
P. cordatum	8.96	0.00	9.09	0.00	6.81
O. reflexa	2.99	0.00	6.49	8.00	4.71
A. ligamentina	4.48	4.55	2.60	4.00	3.66
Q. quadrula	1.49	4.55	2.60	8.00	3.14
F. ebena	1.49	0.00	2.60	0.00	1.57
P. alatus	1.49	4.55	0.00	4.00	1.57
L. ovata	2.99	4.55	0.00	0.00	1.57
T. truncata	0.00	0.00	2.60	0.00	1.05
A. p. plicata	1.49	0.00	1.30	0.00	1.05
E. lineolata	1.49	0.00	0.00	0.00	0.52
F. subrotunda	0.00	0.00	0.00	4.00	0.52
L. costata	0.00	0.00	1.30	0.00	0.52
F. flava	1.49	0.00	0.00	0.00	0.52
Total individuals	67	22	77	25	191
Total species	13	7	11	8	16
Species diversity (H')	1.86	1.60	1.78	1.72	1.89
Evenness	0.67	0.96	0.67	0.88	0.61
Individuals < 30 mm, %	0.0	0.0	9.1	0.0	3.7
Species < 30 mm, %	0.0	0.0	27.3	0.0	18.7

Relationships between Unionidae and *C. fluminea*

The relationships between total numbers and biomass of Unionidae versus *C. fluminea* were plotted for 1992 and 1993 combined (Figures 19 and 20). Relationships between total density of Asian clams and native mussels were not significant ($p > 0.05$) for either year (Table 11). The relationship between biomass of native versus nonindigenous species was negative for both years and significant ($p < 0.01$). Although significant, it should be noted that all plots exhibit a great deal of scatter and correlations are weak. The high n number (>100 samples were used) enhanced the likelihood of significance.

Total density and total biomass of Unionidae in each 0.25-sq-m quadrat collected in 1992 and 1993 were plotted against four particle-size classes (Figures 21-24). Regression equations for density and biomass of *C. fluminea* and total Unionidae versus the four size fractions (<6.35, 6.25-12.7, 12.7-34.0, and >34 mm) of sediment in each of the quadrat samples were prepared (Table 11). Regression coefficients were significant for

Table 7
Percent Occurrence of Unionidae Collected in the Upper Ohio River Using Quantitative Sampling Methods, July 1993

Species	RM 292.0	RM 290.0	RM 287.2	RM 284.0	Total
Q. p. pustulosa	60.00	35.00	46.00	20.00	38.46
E. crassidens	55.00	25.00	32.00	12.50	28.46
Q. metanevra	20.00	20.00	8.00	5.00	10.77
P. cordatum	30.00	0.00	12.00	0.00	9.23
O. reflexa	10.00	0.00	10.00	5.00	6.92
A. ligamentina	10.00	5.00	4.00	2.50	4.62
Q. quadrula	5.00	5.00	4.00	5.00	4.62
F. ebena	5.00	0.00	4.00	0.00	2.31
P. alatus	5.00	5.00	0.00	2.50	2.31
L. ovata	10.00	5.00	0.00	0.00	2.31
T. truncata	0.00	0.00	4.00	0.00	1.54
A. p. plicata	5.00	0.00	2.00	0.00	1.54
E. lineolata	5.00	0.00	0.00	0.00	0.77
F. subrotunda	0.00	0.00	0.00	2.50	0.77
L. costata	0.00	0.00	2.00	0.00	0.77
F. flava	5.00	0.00	0.00	0.00	0.77
Total samples	20	20	50	28	118
Total species	13	7	11	8	16

C. fluminea density and biomass for all four sizes classes ($p < 0.01$). Relationships were positive for the three smaller size classes, but negative for particle sizes greater than 34 mm. In other words, density and biomass of *C. fluminea* were positively related to small and medium-sized particles, but negatively related to large-sized particles.

Significant relationships ($p > 0.05$) were not found between density of Unionidae and the four particle sizes. Biomass of Unionidae was not related significantly to quantities of the two smaller sized particles. However, there were significant positive relationships between biomass of Unionidae and the percentage of large-sized particles. These results indicated that, to some extent, Unionidae are favored by presence of large-sized and, hence, more stable particles.

Substratum relationships

At RM 287.2 divers distinguished between mussels that were buried in the substratum versus those lying on their side on top of the substratum. This was accomplished by placing collected mussels in one of two bags depending on their position in the substratum. The majority of the *E. crassidens* were buried in (67.5 percent) as compared with lying on the surface (23.5 percent) (Table 12). *Quadrula pustulosa pustulosa* was

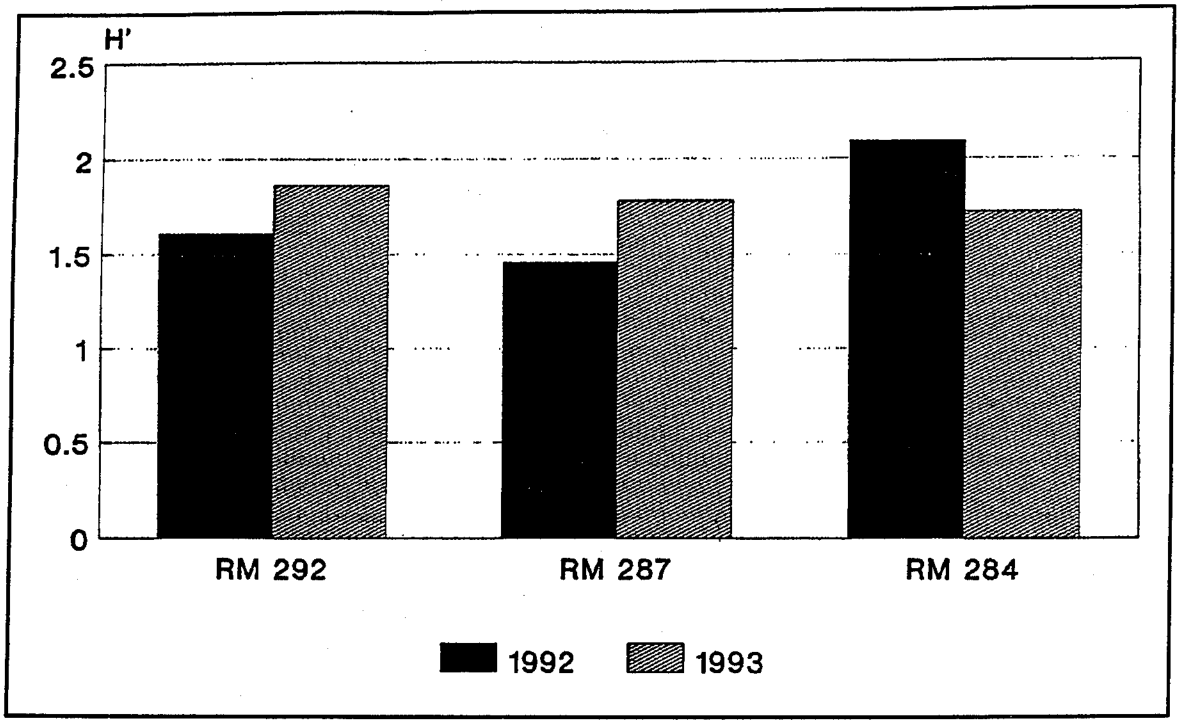


Figure 10. Species diversity (H') at three locations, 1992 and 1993

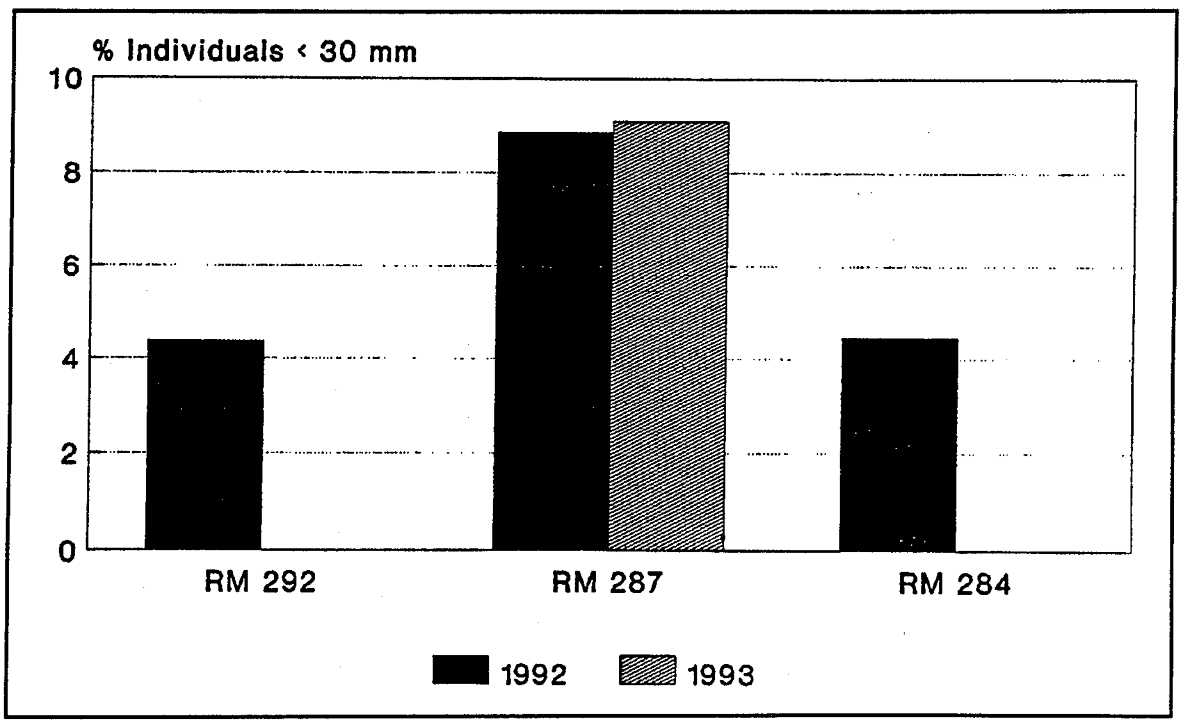


Figure 11. Evidence of recent recruitment and percent individuals <30 mm total shell length at three locations, 1992 and 1993

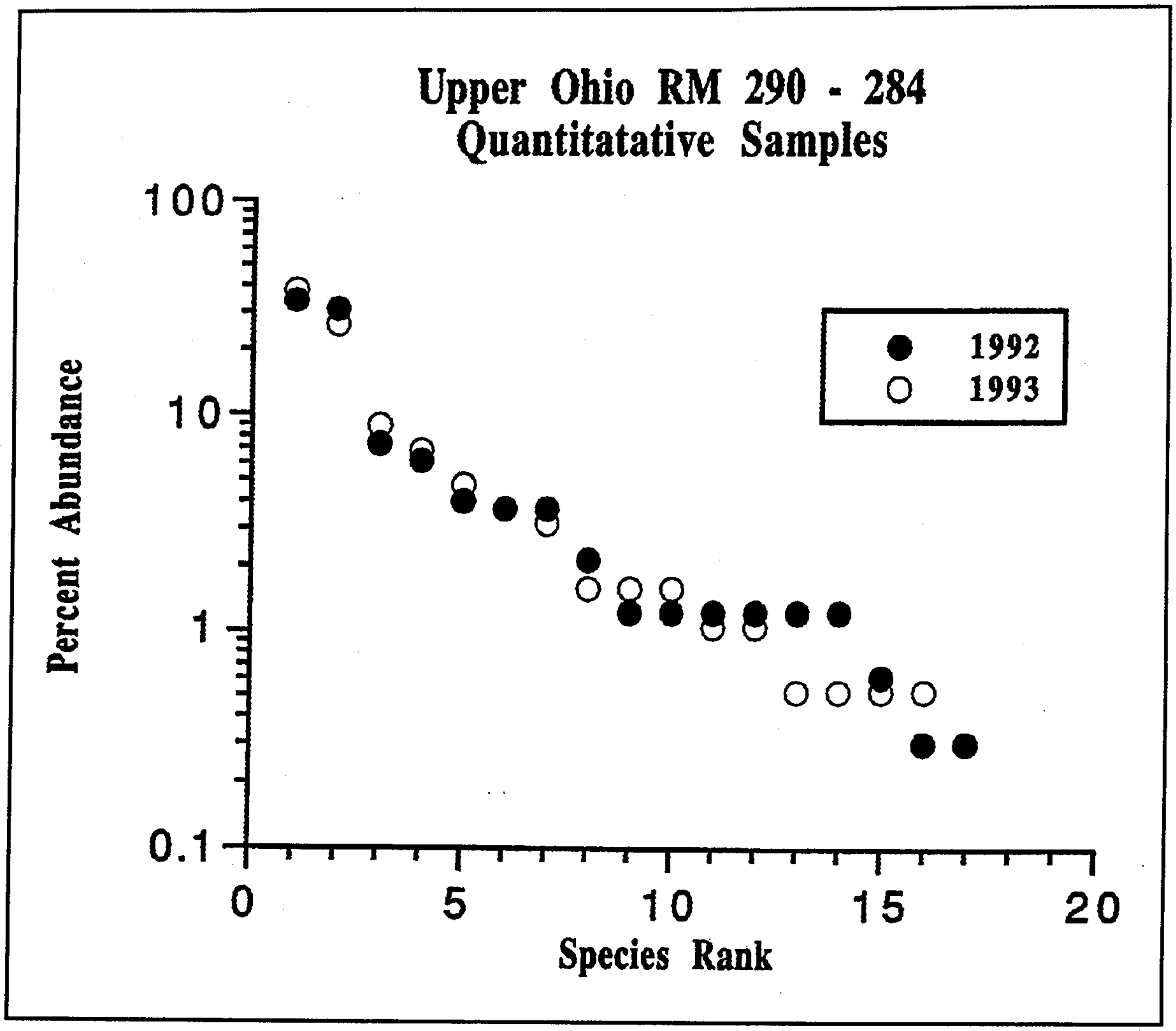


Figure 12. Relationship between percent abundance and species rank for mussels collected using quantitative methods, 1992 and 1993

about equally abundant on the surface as buried, although *P. cordatum* was 5.6 times more abundant buried (9.7 percent) than it was lying on top of the substratum (1.74 percent). Conversely, two large species, *Megalonaias nervosa* and *Q. metanevra,* were 30.5 and 11.8 times more common on the surface than buried in the substratum.

Size Demography of Dominant Populations

Two native unionid species were collected in sufficient numbers for demographic analysis. These two species were *E. crassidens* and *Q. p. pustulosa*, both of which have massive shells. *Elliptio crassidens* grows to large adult size (maximum length of approximately 120 mm) and is long-lived (approximately 25 years). *Quadrula pustulosa pustulosa* grows to moderate adult size (maximum length of approximately 70 mm)

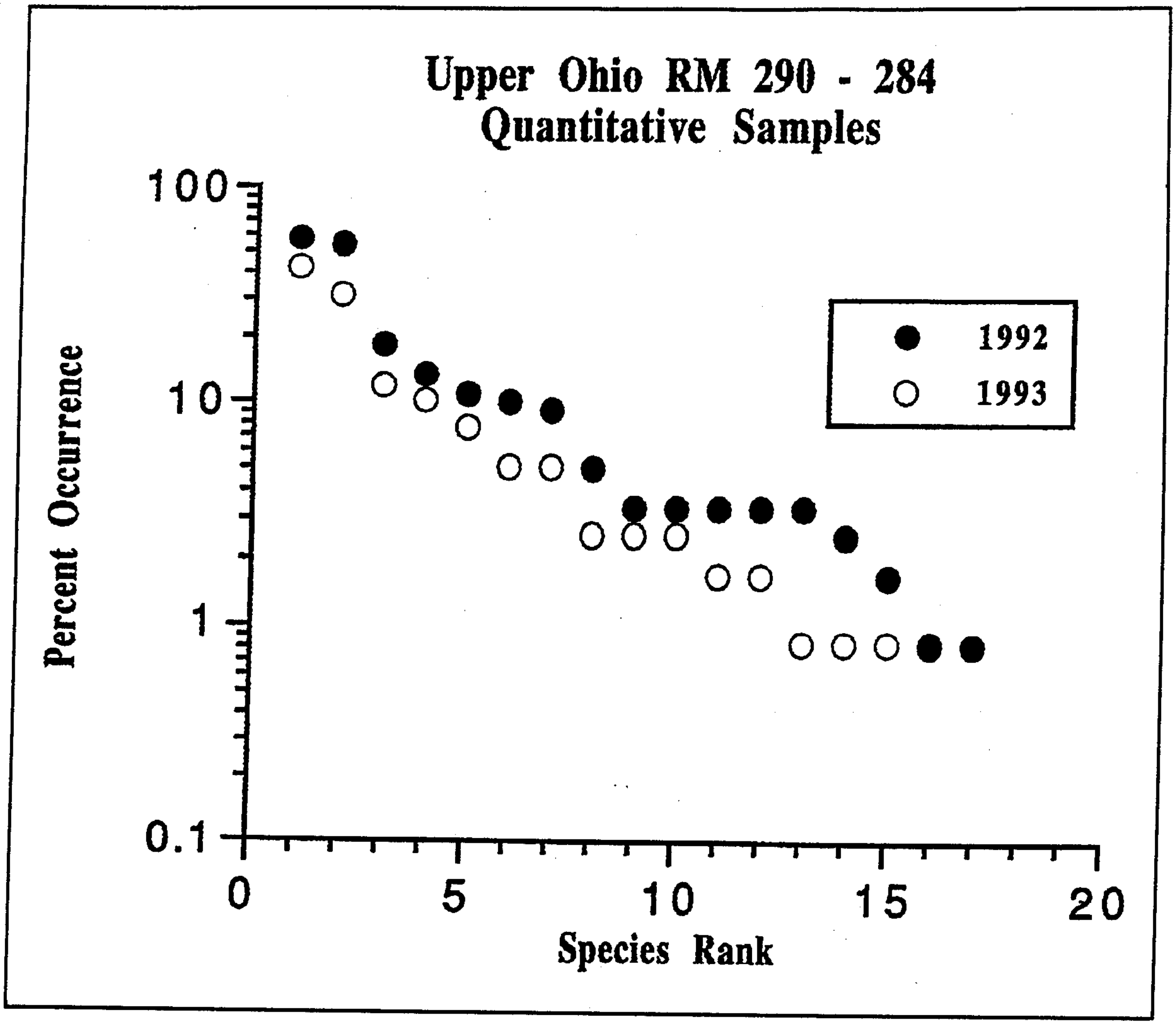


Figure 13. Relationship between percent occurrence and species rank for mussels collected using quantitative methods, 1992 and 1993

and is moderately long-lived (approximately 12 years). In addition, size demography of the Asian clam, *C. fluminea*, was examined. *Corbicula fluminea* is small (maximum length in a population is typically 35 mm) and short-lived (<3 years) compared with native unionids. *Corbicula fluminea* populations often show recruitment in both spring and fall of each year.

The two native unionid species were approximately equally abundant at all locations, and there were no clear intersite differences in size demography. In contrast, *C. fluminea* declined greatly in density between RM 292.0 and 284.0 (moving upriver), and size demography of the population was slightly different at the two upriver sites than at the two downriver sites. These patterns are described in more detail below.

Corbicula fluminea. At all locations (i.e., RM 284.0, 287.2, 289.9, and 292.0), the *C. fluminea* population was dominated by individuals of a single size cohort with average length of approximately 21 mm

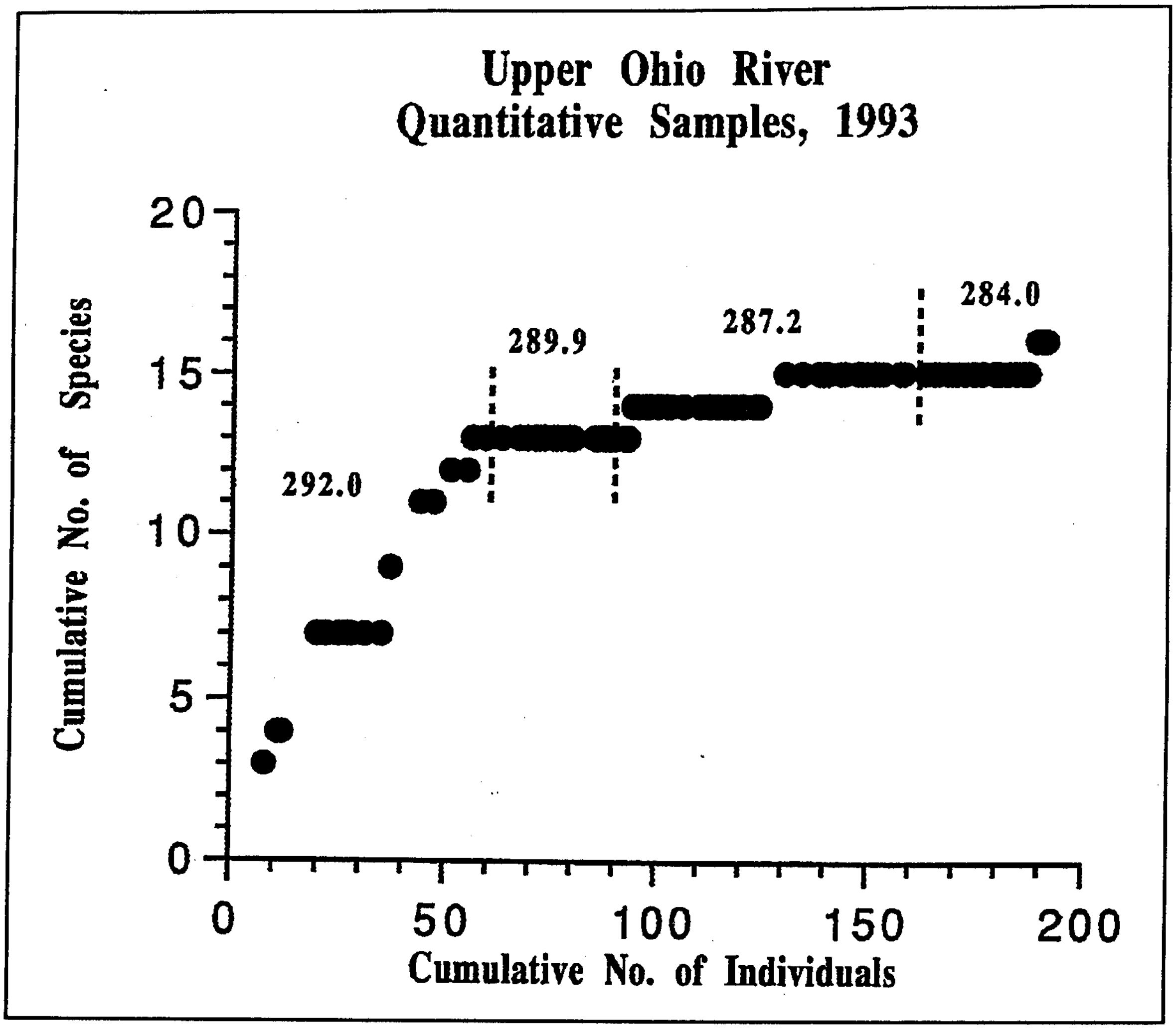


Figure 14. Relationship between cumulative number of individuals and cumulative number of species collected using quantitative methods, 1993

(Figures 25-28). The size structures of population samples from RM 284.0 and 287.2 were virtually identical (Figures 25 and 26) as were the samples from RM 289.9 and 292.0 (Figures 27 and 28). However, there were marked differences in size structures between the two upriver versus the two downriver sites. The combined samples from RM 284.0 and 287.2 included relatively few mussels less than 18 mm in length (Figure 29). At these upriver locations there was evidence of a small cohort with average length of approximately 11 mm (11 individuals ranging in length from 9 to 13 mm), but the relative abundance of this cohort was minuscule (0.6 percent) due to the great abundance of larger *C. fluminea*. In contrast, this small cohort was considerably more prominent in the size demography of combined samples from RM 289.9 and 292.0 (Figure 30). Nearly three times more individuals ranging in length from 9 to 13 mm were collected at these two locations than at the two upriver locations, and the relative abundance of this small cohort at the downriver sites (4.8 percent) was eight times higher than at the upriver sites. In absolute terms,

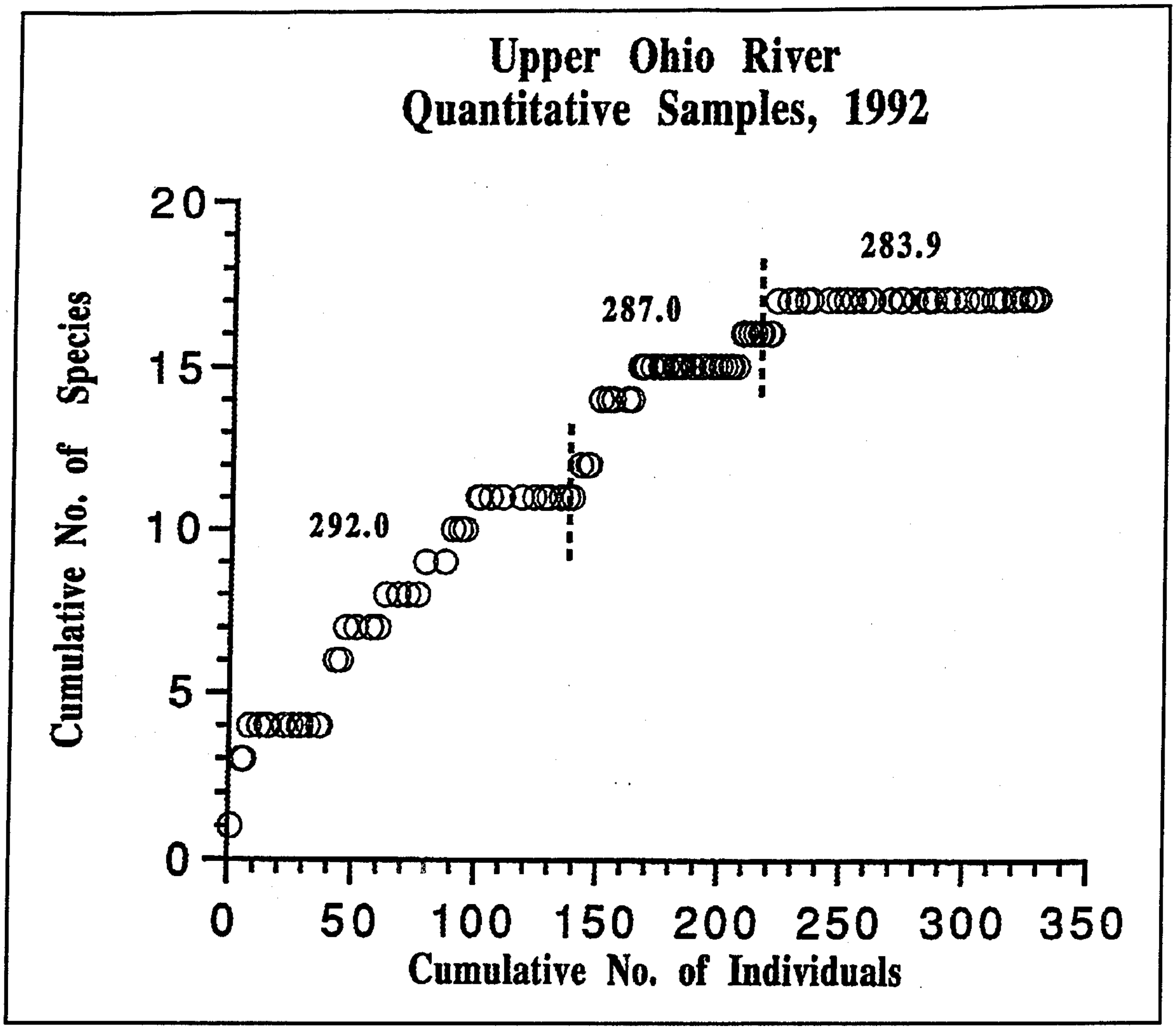


Figure 15. Relationship between cumulative number of individuals and cumulative number of species collected using quantitative methods, 1992

the downriver sites had more small and fewer large *C. fluminea* than the upriver sites.

Due to the lesser abundance of large and greater abundance of small *C. fluminea* at the downriver sites, an additional cohort of relatively small mussels could be discerned in the length-frequency histogram at RM 289.9 and 292.0 (Figure 30). This cohort of small individuals had a minimum length of 13 mm and an average length of 16.5 mm. Its maximum length was obscured by the lower part of the size range of the heavily dominant cohort of mussels with an average length of approximately 21 mm. The extremely high relative abundance of large *C. fluminea* at the upriver sites (RM 284.0 and 287.2) was such that the intermediate-sized cohort with an average length of 16.5 mm was entirely obscured by the lower part of the size range of the heavily abundant cohort with an average length of approximately 21 mm (Figure 29).

Table 8
Density and Biomass for *Corbicula fluminea* and Unionidae Collected at Four Locations in the Upper Ohio River, July 1993

RM	Density (Individuals/sq m)	SE[1]	Biomass (g/sq m)	SE[1]
		Corbicula fluminea		
292.0	65.6[c]	7.1	230.1[c]	24.1
289.9	54.6[c]	10.5	174.5[c]	37.6
287.2	537.4[b]	49.4	1,786.6[b]	145.4
284.0	821.1[a]	104.2	2,935.9[a]	314.0
F		27.5		38.6
Pr > F		0.0001		0.0001
		Unionidae		
292.0	13.4[a]	2.0	2,119.7[a]	294.1
289.9	4.4[b]	1.1	662.2[b]	161.3
287.2	6.2[b]	0.8	773.1[b]	124.9
284.0	3.6[b]	0.7	414.4[b]	103.9
F		12.4		16.3
Pr > F		0.0001		0.0001

[1] SE = standard error of the mean.

Few large *C. fluminea* were collected. The upper size limit of the extremely dominant cohort with an average length of 21 mm was certainly no greater than 25 mm (Figures 29 and 30). Only at RM 287.2 was there an appreciable number of individuals longer than 25 mm (Figure 26). At this site there were 20 individuals between 25 and 30 mm, but this still represented only 1.9 percent of the population. At the other upriver site (RM 284.0), seven individuals (0.5 percent of the population) were collected that measured longer than 25 mm (Figure 25). Only a single individual (0.4 percent of the population) greater than 25 mm long was collected at RM 289.9. Two individuals longer than 25 mm (0.6 percent of the population) were collected at RM 292.0. From all four sites, and a grand total of 2,960 *C. fluminea*, only eight individuals (0.3 percent) were greater than 30 mm long. The largest individual collected was 36 mm long (Figure 25).

Elliptio crassidens. Most of the *E. crassidens* were large; 49 of 50 individuals ranged from 84 to 120 mm in length (Figure 31). However, a single, relatively recent recruit was collected that measured 53 mm in length.

Quadrula pustulosa pustulosa. The population of *Q. p. pustulosa* was dominated by relatively large mussels but also included substantial evidence of relatively recent recruitment (Figure 32). Mussels ranging in length from 48 to 70 mm comprised 75 percent of the population. Mussels ranging in length from 18 to 44 mm comprised 25 percent of the

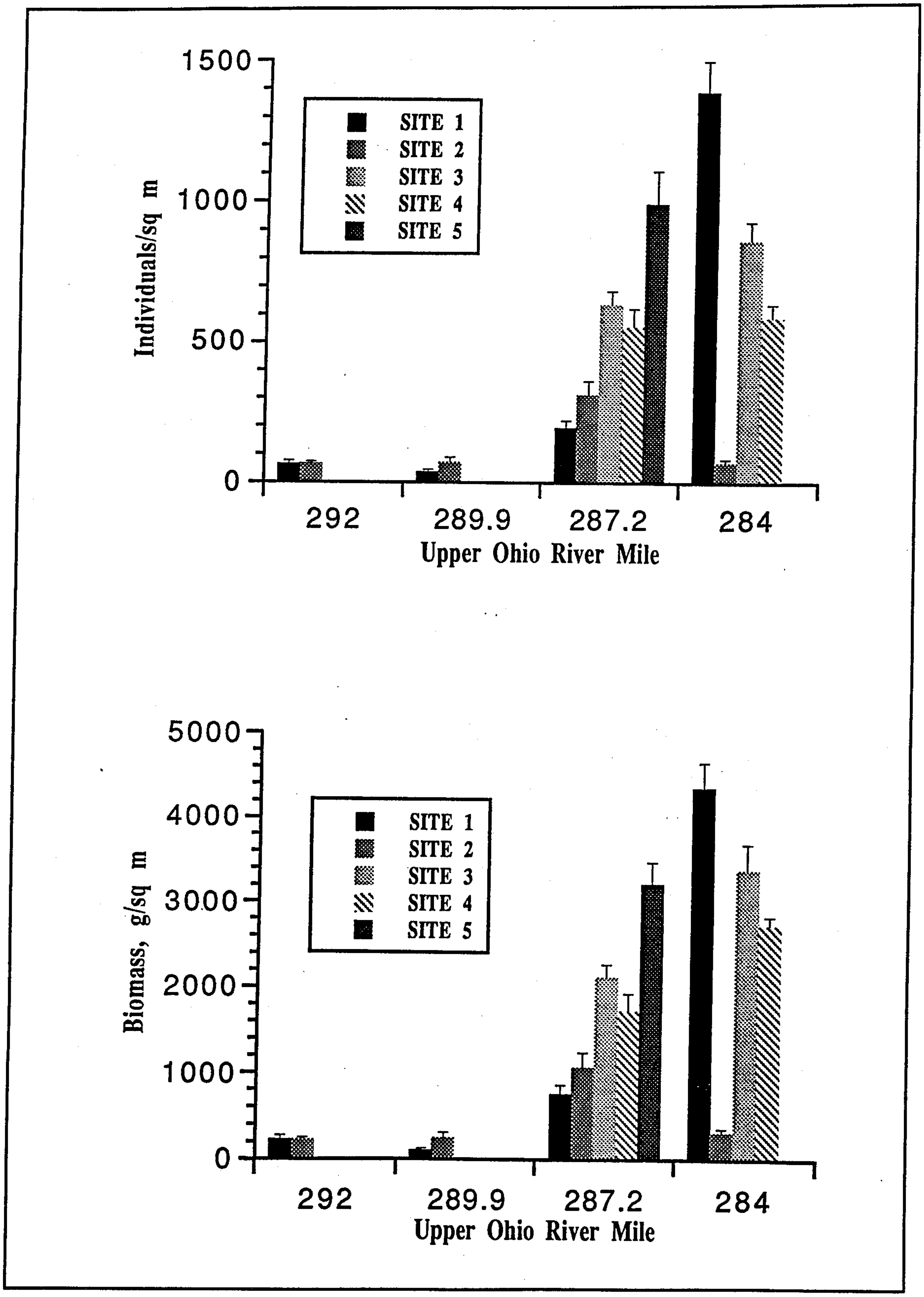


Figure 16. Numerical and biomass density for *C. fluminea* collected at three locations, 1993

Table 9
Density and Biomass for *Corbicula fluminea* Collected at Four Locations in the Upper Ohio River, July 1993

RM	Site	Density (Individuals/sq m)	SE[1]	Biomass, g/sq m	SE[1]
292.0	1	64.8[a]	12.6	230.6[a]	43.4
292.0	2	66.4[a]	7.3	229.6[a]	24.1
F		0.91		0.00	
Pr > F		0.01		0.98	
289.9	1	38.0[a]	8.0	104.2[a]	22.6
289.9	2	71.2[a]	18.3	244.8[a]	66.1
F		2.75		4.05	
Pr > F		0.11		0.0594	
287.2	1	192.8[c]	28.0	760.3[c]	102.5
287.2	2	311.6[c]	50.2	1,077.0[c]	168.8
287.2	3	634.8[b]	48.5	2,129.4[b]	144.8
287.2	4	556.0[b]	65.9	1,743.0[b]	189.7
287.2	5	1,025.2[a]	116.2	3,223.5[a]	253.9
F		20.5		29.2	
Pr > F		0.0001		0.0001	
284.0	1	1,387.2[a]	109.7	4,364.6[a]	299.5
284.0	2	74.6[d]	12.2	308.1[c]	49.3
284.0	3	861.3[b]	66.5	3,390.2[b]	298.7
284.0	4	586.7[c]	48.6	2,728.1[b]	103.7
F		42.7		45.3	
Pr > F		0.0001		0.0001	

[1] SE = standard error of the mean.

population. Four mussels measured less than 30 mm in length, representing very recent recruitment to the population.

Effects of Vessel Passage on Current Velocity

The sensor for a Marsh McBirney Model 527 water velocity meter was placed about 10 cm above the mussel bed along the left descending bank (LDB) at RM 287. Data on ambient water velocity were collected at three times during the day (Figures 33-35). The instrument was coupled to a data logger so that velocity at right angles to the bank (a sensor was pointed toward the channel) and parallel to shore could be recorded at 1-sec intervals. These data were used to calculate combined or net flow. Direction of flow was calculated from these readings and from continuous compass readings. Maximum, minimum, mean, and standard deviation (a simple measure of water turbulence) were then calculated. These

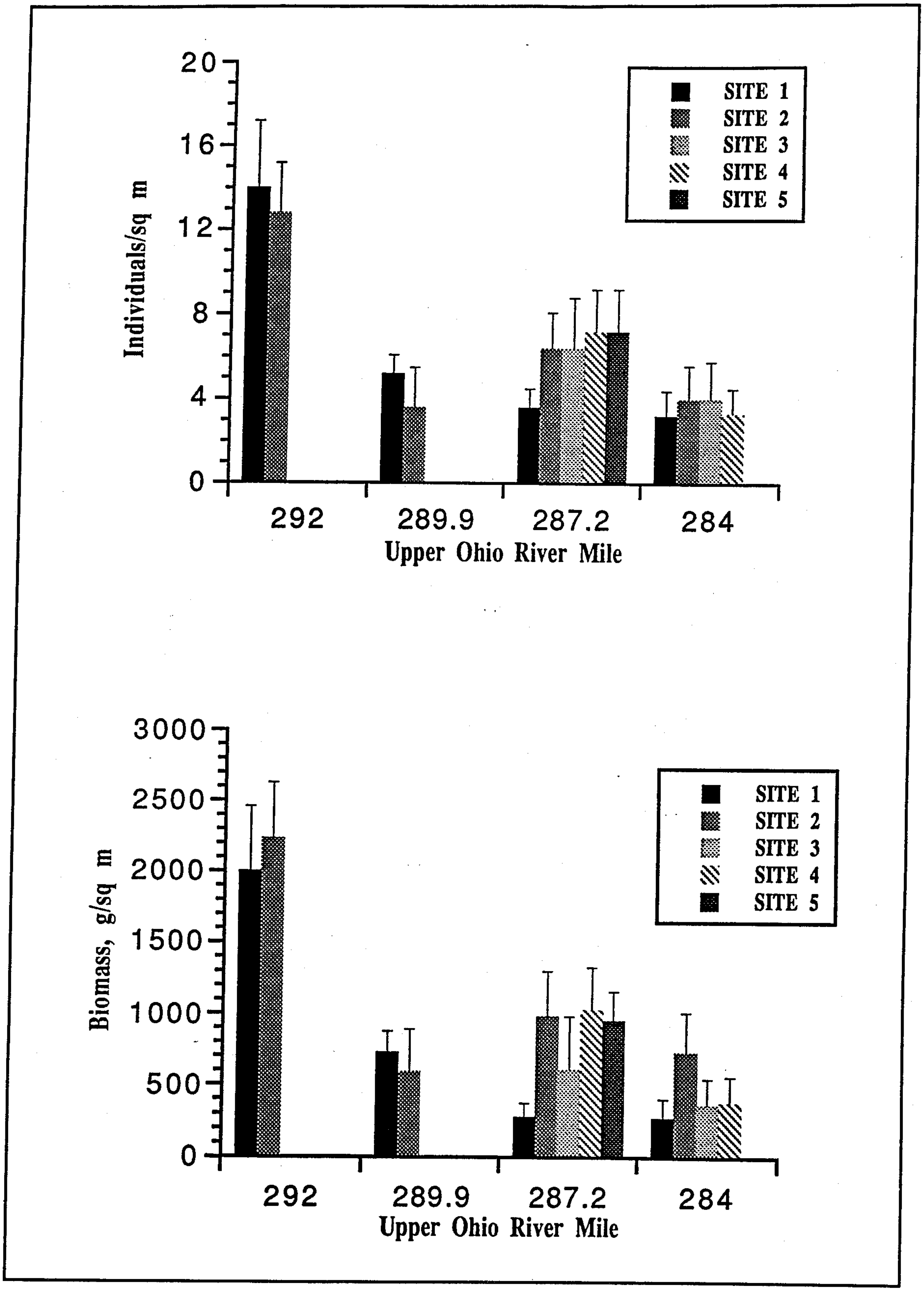


Figure 17. Numerical and biomass density for Unionidae collected at three locations, 1993

Table 10
Density and Biomass for Unionidae Collected at Four Locations in the Upper Ohio River, July 1993

RM	Site	Density (Individuals/sq m)	SE[1]	Biomass, g/sq m	SE[1]
292.0	1	14.0[a]	3.2	2,003.0[a]	455.1
292.0	2	12.8[a]	2.4	2,236.4[a]	393.9
F		0.09		0.15	
Pr > F		0.77		0.70	
289.9	1	5.2[a]	0.9	728.7[a]	147.1
289.9	2	3.6[a]	1.9	595.6[a]	295.4
F		0.58		0.16	
Pr > F		0.46		0.69	
287.2	1	3.6[a]	0.9	281.2[a]	93.5
287.2	2	6.4[a]	1.7	985.5[a]	315.3
287.2	3	6.4[a]	2.4	609.6[a]	373.0
287.2	4	7.2[a]	2.0	1,033.1[a]	298.2
287.2	5	7.2[a]	2.0	955.8[a]	205.7
F		0.64		1.40	
Pr > F		0.63		0.26	
284.0	1	3.2[a]	1.2	275.4[a]	128.0
284.0	2	4.0[a]	1.6	732.3[a]	279.8
284.0	3	4.0[a]	1.8	363.6[a]	182.0
284.0	4	3.3[a]	1.2	379.1[a]	178.5
F		0.08		0.90	
Pr > F		0.97		0.46	

[1] SE = standard error of the mean.

summary statistics were calculated for an increment of time, usually 200 sec. Effects of vessel passage were determined by comparison of a 200-sec interval of time during passage compared with the same amount of data collected during a time when no vessel passed the site.

Under ambient conditions, minimum velocity parallel to shore (normal to flow, on the Y-axis) ranged from 0.236 to 0.327 ft/sec for Tests 1 to 3 (ambient conditions, Table 13). Maximum velocity ranged from 0.365 to 0.[illegible]8 ft/sec. The standard deviation of Tests 1, 2, and 3 was 0.043, 0.038, and 0.029 ft/sec, respectively.

Test 4 illustrates the manner in which a commercial vessel affects mean water velocity. A tug with 10 loaded barges was moving downriver approximately 400 ft from the LDB. The velocity sensor was over the mussel bed at a distance about 75 ft offshore. The vessel was moving downriver at approximately 10.2 ft/sec (equal to about 6.9 mph). Velocity normal to flow decreased from approximately 0.4 ft/sec to less than

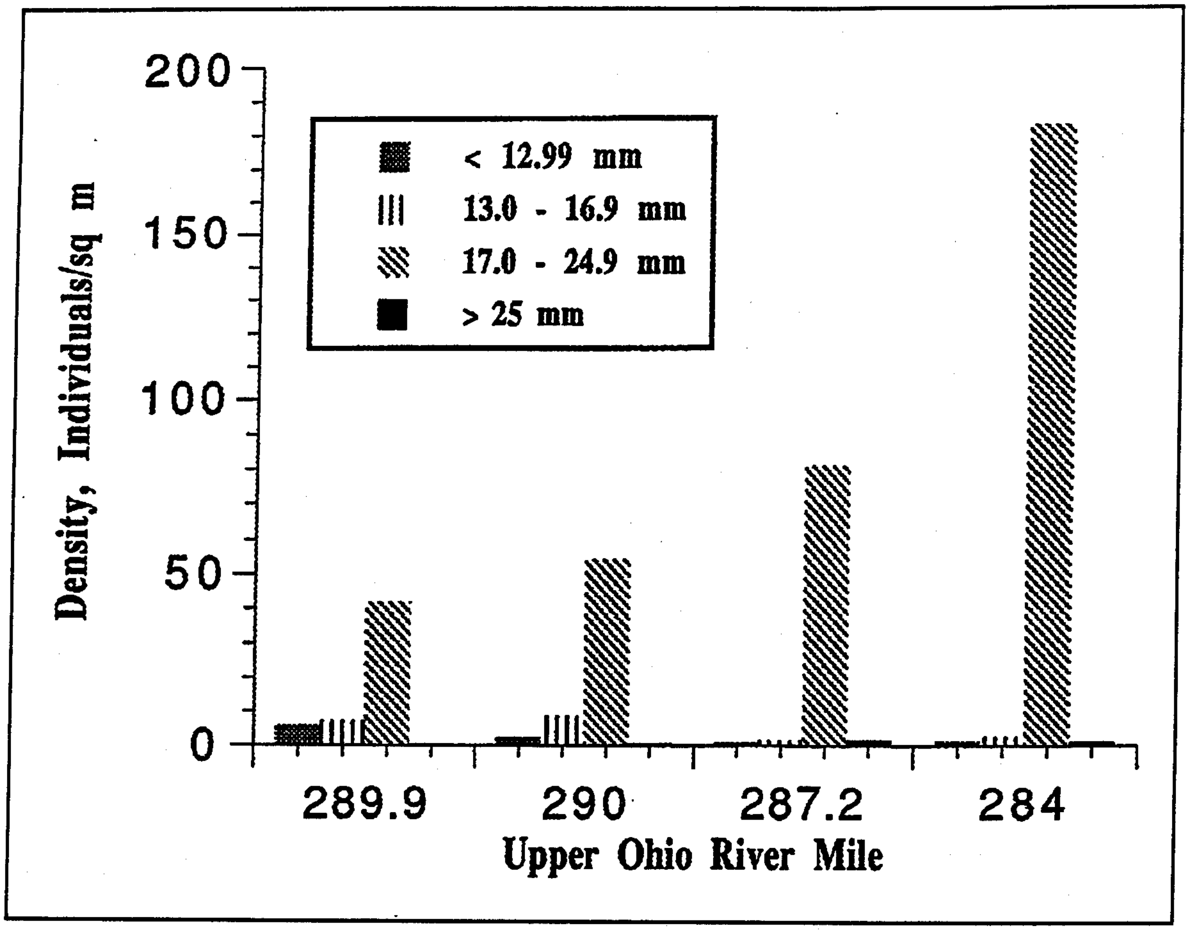
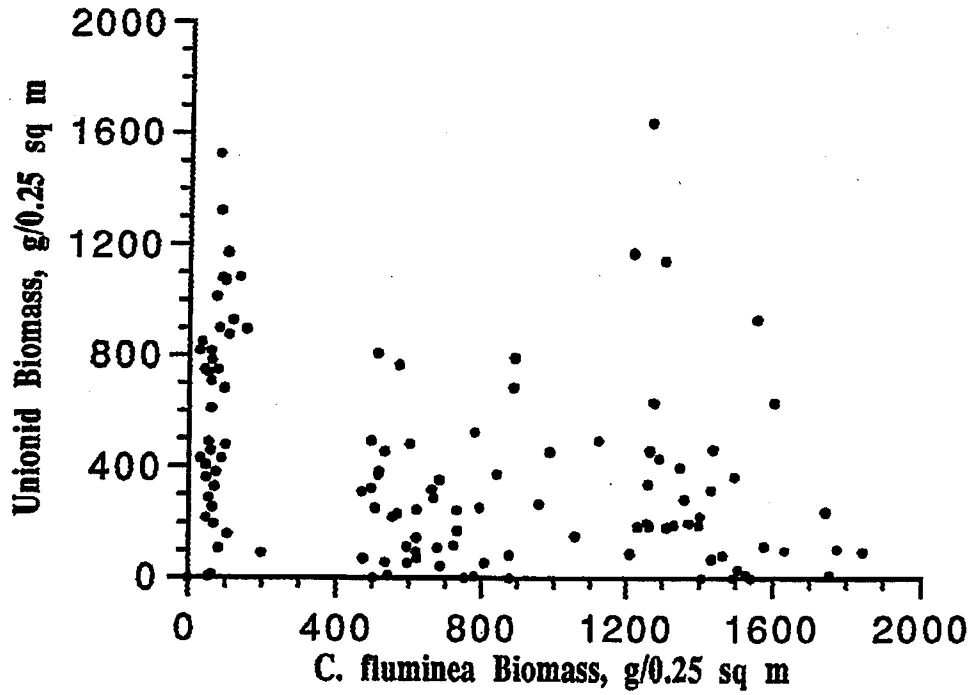


Figure 18. Density of four size classes of *C. fluminea* at four locations, 1993

0.2 ft/sec (Figure 36). Net velocity showed the same magnitude of change although there was little effect on direction of flow. Standard deviation of the individual velocity readings as the vessel passed was greater (0.059 ft/sec) than during a 200-sec interval after the vessel had passed (0.036 ft/sec, Table 13). This can be compared with standard deviation readings collected during ambient conditions (for Tests 1, 2, and 3 standard deviation was calculated at 0.043, 0.038, and 0.029). Minimum velocity during the time interval when the vessel passed (0.129 ft/sec) was much less than the minimum values collected during ambient conditions or after Test 4 had taken place.



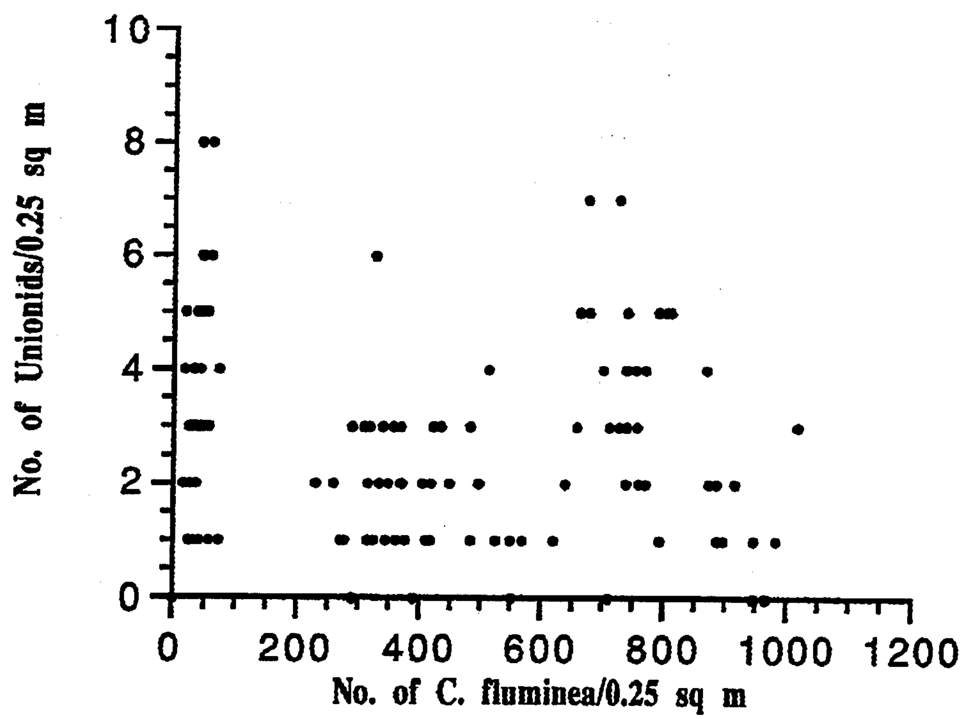


Figure 19. Relationship between unionid biomass and *C. fluminea* biomass, and unionid density and *C. fluminea* density, 1992

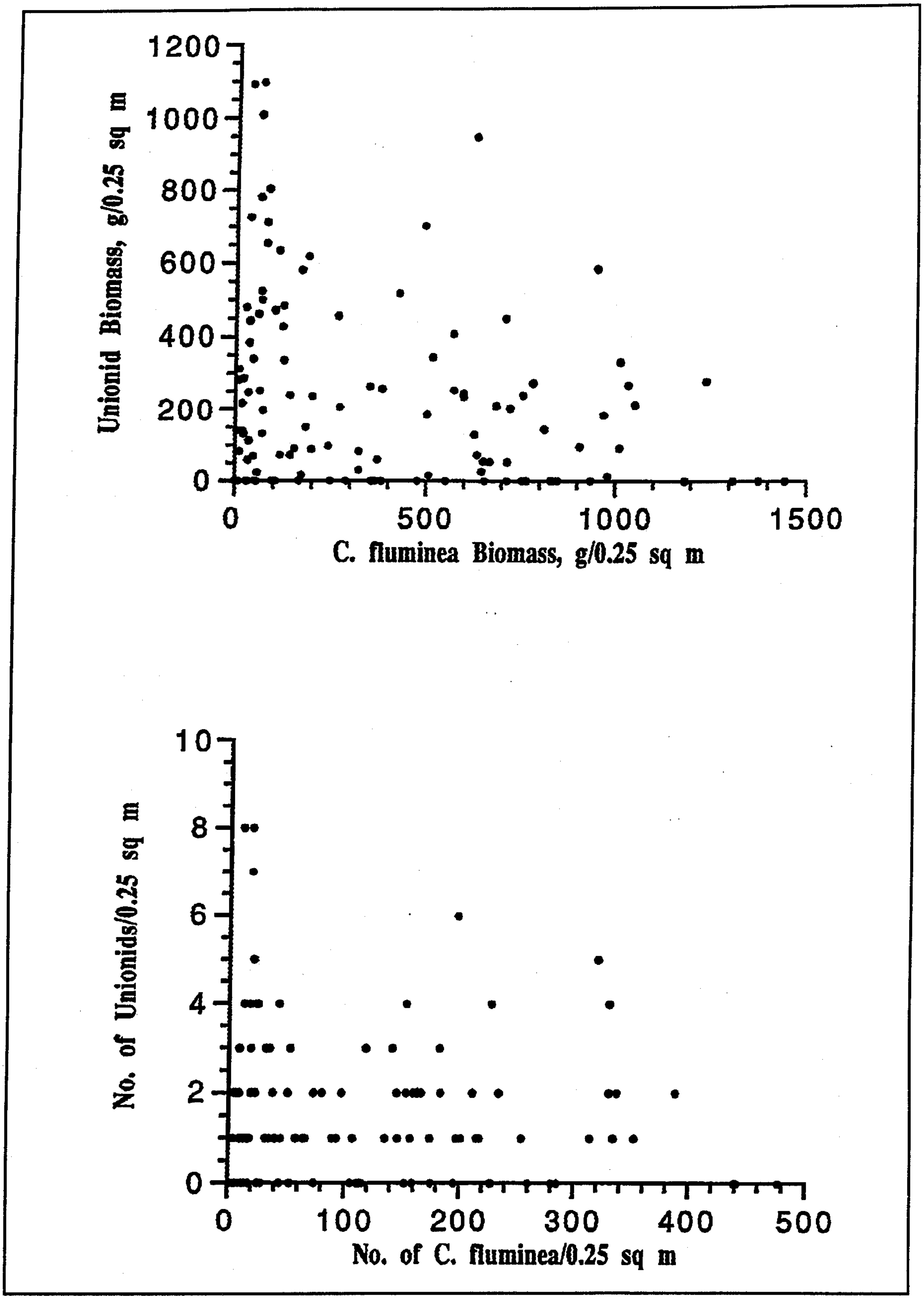


Figure 20. Relationship between unionid biomass and *C. fluminea* biomass, and unionid density and *C. fluminea* density, 1993

Table 11
Regression Equations Relating Partical Sizes of the Substratum with *C. fluminea* Density and Biomass, 1992 and 1993 Combined

Partical Size, mm	Equation	n	r	p
y = Unionidae, x = *C. fluminea*				
1992 Density	y = -0.00087x + 3.1	120	-0.16	> 0.05
1992 Biomass	y = -0.20826x + 544.1	120	-0.32	< 0.01
1993 Density	y = -0.00201x + 1.8	118	-0.14	> 0.05
1993 Biomass	y = -0.17152x + 289.6	118	-0.24	< 0.01
y = *C. fluminea* Density, x = Percent of a Specific Grain Size				
< 6.35	y = 10.3x - 110.8	197	0.42	< 0.01
6.35 - 12.7	y = 61.9x - 298.0	197	0.63	< 0.01
12.7 - 34	y = 25.3x - 248.3	197	0.74	< 0.01
> 34	y = -10.4x + 617.2	197	-0.69	< 0.01
y = *C. fluminea* Biomass, x = Percent of a Specific Grain Size				
< 6.35	y = 19.4x - 184.4	197	0.45	< 0.01
6.35 - 12.7	y = 102.0x - 402.5	197	0.58	< 0.01
12.7 - 34	y = 46.6x - 421.0	197	0.76	< 0.01
> 34	y = -19.0x + 1,168.4	197	-0.70	< 0.01
y = Unionidae Density, x = Percent of a Specific Grain Size				
< 6.35	y = -0.0003x + 2.4	197	-0.002	> 0.05
6.35 - 12.7	y = 0.0507x + 1.9	197	0.08	> 0.05
12.7 - 34	y = -0.2443x + 2.8	197	-0.11	> 0.05
> 34	y = 0.0036x + 2.2	197	0.04	> 0.05
y = Unionidae Biomass, x = Percent of a Specific Grain Size				
< 6.35	y = -3.4x + 463.6	197	-0.12	> 0.05
6.35 - 12.7	y = -6.4x + 395.6	197	-0.06	> 0.05
12.7 - 34	y = 46.6x - 420.9	197	0.76	< 0.01
> 34	y = 3.3x + 226.2	197	0.19	< 0.01

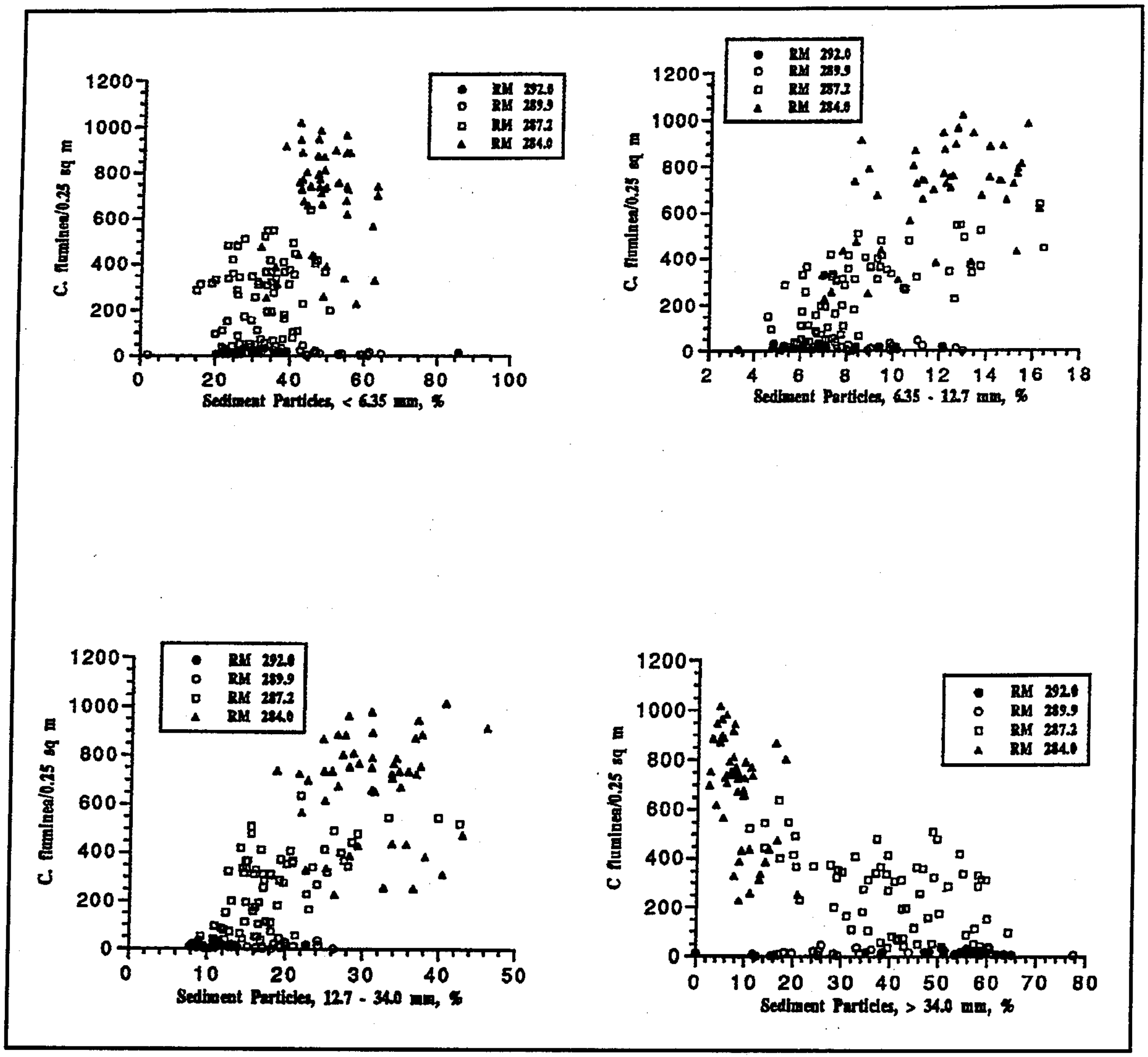


Figure 21. Relationship between four size classes of sediment particles and density of *C. fluminea*, 1992 and 1993 data combined

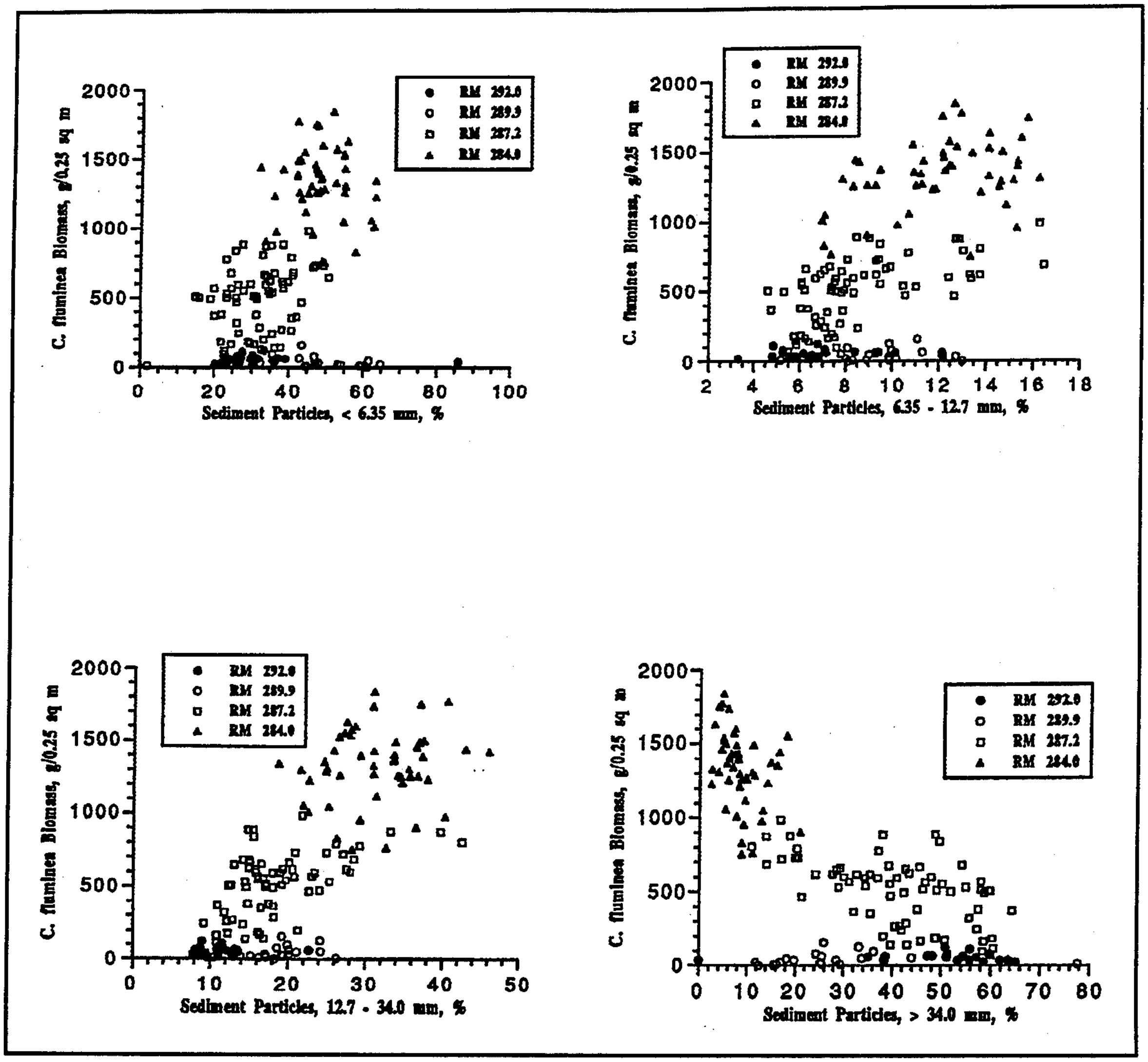


Figure 22. Relationship between four size classes of sediment particles and biomass density of *C. fluminea*, 1992 and 1993 data combined

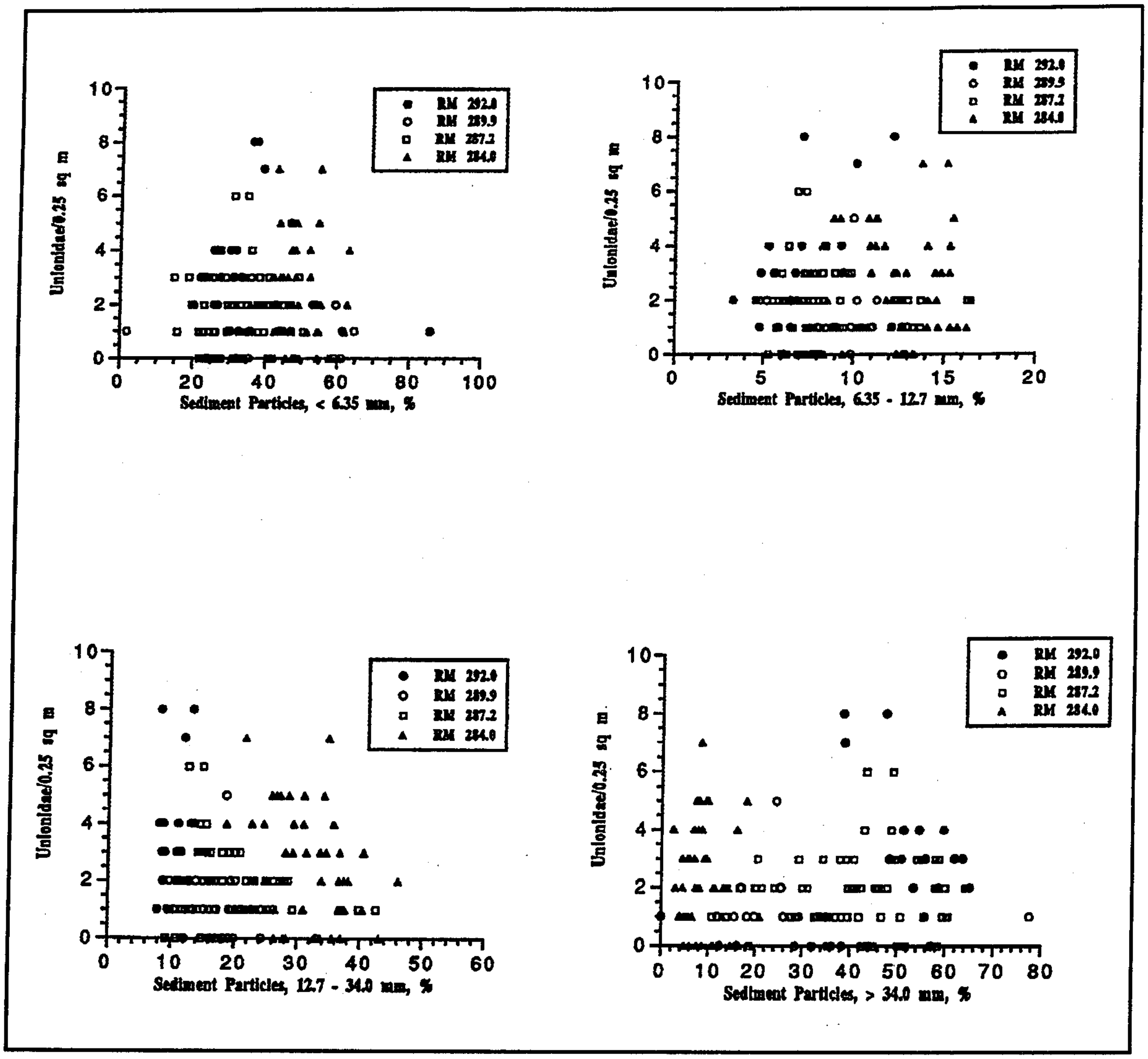


Figure 23. Relationship between four size classes of sediment particles and density of Unionidae, 1992 and 1993 data combined

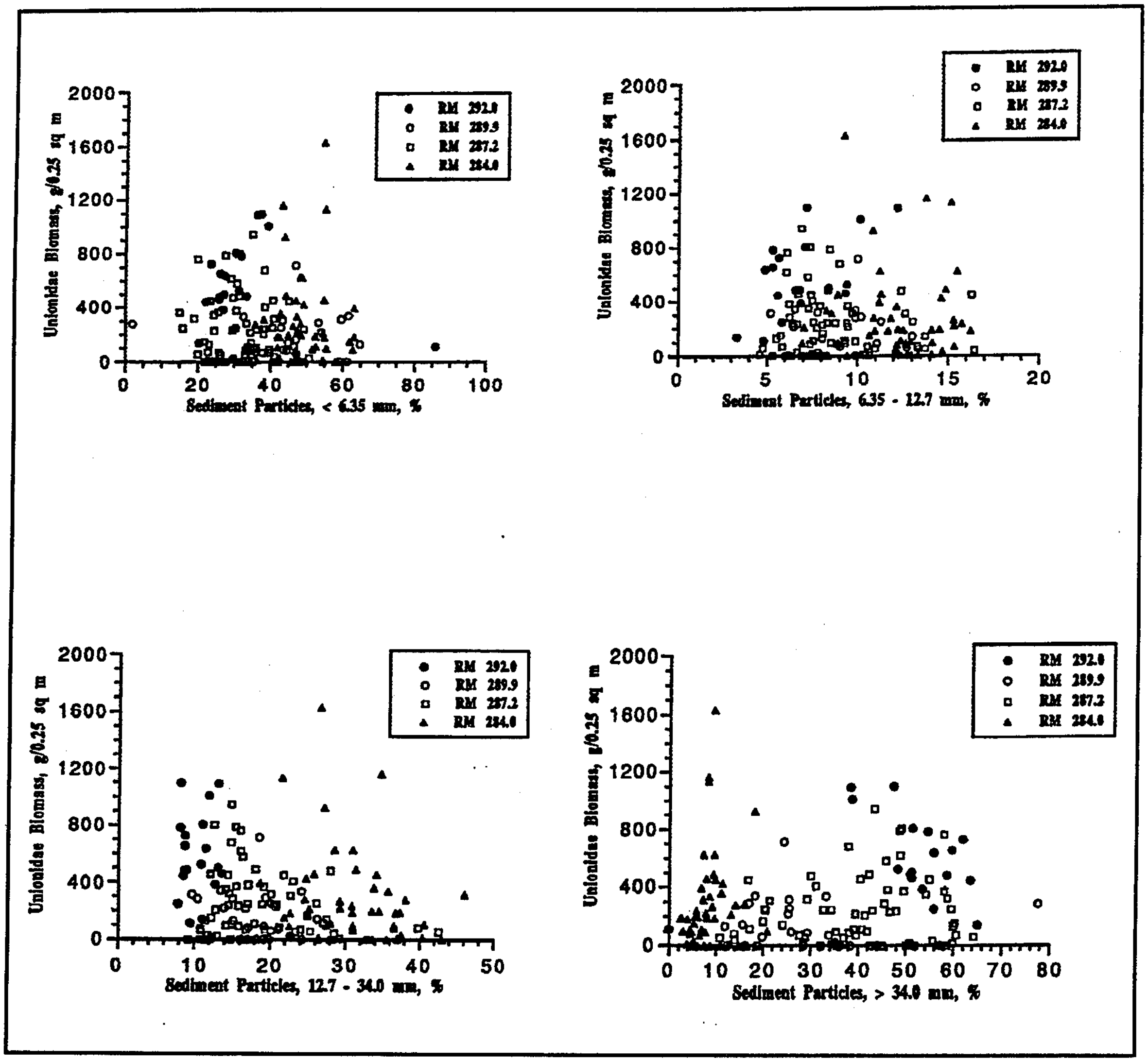


Figure 24. Relationship between four size classes of sediment particles and biomass density of Unionidae, 1992 and 1993 data combined

Table 12
Comparison Between Species Abundance and Frequency of Mussels that were Buried in Substratum Versus Lying on Top of the Substratum, RM 287.2, 18 July 1993

	Abundance		Frequency	
Species	**Surface**	**Buried**	**Surface**	**Buried**
E. crassidens	23.48	67.50	61.90	98.81
Q. pustulosa	16.52	12.94	61.90	78.57
P. cordatum	1.74	9.71	9.52	70.24
F. ebena	0.00	2.21	0.00	23.81
Q. metanevra	20.87	1.76	71.43	21.43
A. ligamentina	1.74	1.76	4.76	25.00
A. p. plicata	1.74	1.69	9.52	23.81
M. nervosa	22.61	0.74	57.14	11.90
P. alatus	1.74	0.74	9.52	9.52
P. coccineum	1.74	0.37	9.52	5.95
Q. nodulata	0.00	0.22	0.00	1.19
E. lineolata	0.00	0.22	0.00	3.57
L. ovata	4.35	0.07	14.29	1.19
Q. quadrula	0.00	0.07	0.00	1.19
O. reflexa	1.74	0.00	9.52	0.00
F. flava	0.87	0.00	4.76	0.00
E. dilatata	0.87	0.00	4.76	0.00
Total individuals	115	1,360		
Total samples			21	84

```
                    PERCENTAGE OF SHELLEN

SHELLEN                                      CUM                CUM
                                     FREQ    FREQ   PERCENT   PERCENT

     5  |                              0       0     0.00      0.00
     6  |                              0       0     0.00      0.00
     7  |                              0       0     0.00      0.00
     8  |                              0       0     0.00      0.00
     9  |                              1       1     0.08      0.08
    10  |                              3       4     0.23      0.31
    11  |                              4       8     0.31      0.61
    12  |                              0       8     0.00      0.61
    13  |                              0       8     0.00      0.61
    14  |                              0       8     0.00      0.61
    15  |                              1       9     0.08      0.69
    16  |                              6      15     0.46      1.15
    17  |**                           22      37     1.68      2.83
    18  |****                         54      91     4.13      6.95
    19  |*************               167     258    12.76     19.71
    20  |*********************       281     539    21.47     41.18
    21  |*************************   330     869    25.21     66.39
    22  |**********************      289    1158    22.08     88.46
    23  |*********                   116    1274     8.86     97.33
    24  |**                           25    1299     1.91     99.24
    25  |                              4    1303     0.31     99.54
    26  |                              2    1305     0.15     99.69
    27  |                              1    1306     0.08     99.77
    28  |                              0    1306     0.00     99.77
    29  |                              0    1306     0.00     99.77
    30  |                              0    1306     0.00     99.77
    31  |                              0    1306     0.00     99.77
    32  |                              0    1306     0.00     99.77
    33  |                              1    1307     0.08     99.85
    34  |                              0    1307     0.00     99.85
    35  |                              1    1308     0.08     99.92
    36  |                              1    1309     0.08    100.00
    37  |                              0    1309     0.00    100.00
    38  |                              0    1309     0.00    100.00
        -----+----+----+----+----+
             5   10   15   20   25

               PERCENTAGE
```

Figure 25. Length-frequency histograms for *C. fluminea*, RM 284.0, 1993 (Note that asterisks do not plot for low n numbers)

PERCENTAGE OF SHELLEN

SHELLEN		FREQ	CUM FREQ	PERCENT	CUM PERCENT
7	|	0	0	0.00	0.00
8	|	0	0	0.00	0.00
9	|	0	0	0.00	0.00
10	|	3	3	0.29	0.29
11	|	2	5	0.19	0.48
12	|	1	6	0.10	0.57
13	|	0	6	0.00	0.57
14	|	3	9	0.29	0.86
15	|	4	13	0.38	1.24
16	|	4	17	0.38	1.62
17	|*	12	29	1.14	2.76
18	|******	59	88	5.62	8.38
19	|********************	210	298	20.00	28.38
20	|***********************************	366	664	34.86	63.24
21	|**************************	272	936	25.90	89.14
22	|*******	71	1007	6.76	95.90
23	|**	16	1023	1.52	97.43
24	|*	6	1029	0.57	98.00
25	|	5	1034	0.48	98.48
26	|*	11	1045	1.05	99.52
27	|	1	1046	0.10	99.62
28	|	0	1046	0.00	99.62
29	|	1	1047	0.10	99.71
30	|	0	1047	0.00	99.71
31	|	1	1048	0.10	99.81
32	|	1	1049	0.10	99.90
33	|	1	1050	0.10	100.00
34	|	0	1050	0.00	100.00
35	|	0	1050	0.00	100.00

```
 -----+----+----+----+----+----+----+
      5   10   15   20   25   30   35
```

PERCENTAGE

Figure 26. Length-frequency histograms for *C. fluminea*, RM 287.2, 1993

PERCENTAGE OF SHELLEN

SHELLEN		FREQ	CUM FREQ	PERCENT	CUM PERCENT
7		0	0	0.00	0.00
8		0	0	0.00	0.00
9	*	4	4	1.47	1.47
10	****	10	14	3.66	5.13
11	****	10	24	3.66	8.79
12	*	4	28	1.47	10.26
13	*	2	30	0.73	10.99
14	*	2	32	0.73	11.72
15	***	9	41	3.30	15.02
16	******	17	58	6.23	21.25
17	****	10	68	3.66	24.91
18	*****	14	82	5.13	30.04
19	**********	28	110	10.26	40.29
20	****************************	76	186	27.84	68.13
21	*************************	69	255	25.27	93.41
22	*****	14	269	5.13	98.53
23	*	3	272	1.10	99.63
24		0	272	0.00	99.63
25		0	272	0.00	99.63
26		0	272	0.00	99.63
27		0	272	0.00	99.63
28		0	272	0.00	99.63
29		0	272	0.00	99.63
30		0	272	0.00	99.63
31		0	272	0.00	99.63
32		0	272	0.00	99.63
33		0	272	0.00	99.63
34		1	273	0.37	100.00
35		0	273	0.00	100.00

```
-----+----+----+----+----+---
     5   10   15   20   25
```

PERCENTAGE

Figure 27. Length-frequency histograms for *C. fluminea*, RM 289.9, 1993

```
                    PERCENTAGE OF SHELLEN

SHELLEN                                              CUM                  CUM
                                             FREQ   FREQ  PERCENT   PERCENT
     6   |                                      0      0     0.00      0.00
     7   |                                      0      0     0.00      0.00
     8   |                                      0      0     0.00      0.00
     9   |                                      0      0     0.00      0.00
    10   |*                                     2      2     0.61      0.61
    11   |*                                     4      6     1.22      1.83
    12   |*                                     4     10     1.22      3.05
    13   |***                                  10     20     3.05      6.10
    14   |*****                                18     38     5.49     11.59
    15   |**                                    6     44     1.83     13.41
    16   |**                                    8     52     2.44     15.85
    17   |***                                   9     61     2.74     18.60
    18   |***                                  11     72     3.35     21.95
    19   |*******                              22     94     6.71     28.66
    20   |****************************         92    186    28.05     56.71
    21   |*****************************        94    280    28.66     85.37
    22   |************                         39    319    11.89     97.26
    23   |**                                    6    325     1.83     99.09
    24   |                                      1    326     0.30     99.39
    25   |                                      1    327     0.30     99.70
    26   |                                      0    327     0.00     99.70
    27   |                                      0    327     0.00     99.70
    28   |                                      0    327     0.00     99.70
    29   |                                      0    327     0.00     99.70
    30   |                                      0    327     0.00     99.70
    31   |                                      1    328     0.30    100.00
    32   |                                      0    328     0.00    100.00
         -----+----+----+----+----+----
              5   10   15   20   25

                 PERCENTAGE
```

Figure 28. Length-frequency histograms for *C. fluminea*, RM 292.0, 1993

```
                    PERCENTAGE OF SHELLEN

SHELLEN                                      CUM            CUM
                                   FREQ     FREQ  PERCENT  PERCENT

     9  |                             1        1     0.04     0.04
    10  |                             6        7     0.25     0.30
    11  |                             6       13     0.25     0.55
    12  |                             1       14     0.04     0.59
    13  |                             0       14     0.00     0.59
    14  |                             3       17     0.13     0.72
    15  |                             5       22     0.21     0.93
    16  |                            10       32     0.42     1.36
    17  |*                           34       66     1.44     2.80
    18  |*****                      113      179     4.79     7.59
    19  |****************           377      556    15.98    23.57
    20  |*************************** 647    1203    27.43    51.00
    21  |**************************  602    1805    25.52    76.52
    22  |***************            360     2165    15.26    91.78
    23  |******                     132     2297     5.60    97.37
    24  |*                           31     2328     1.31    98.69
    25  |                             9     2337     0.38    99.07
    26  |*                           13     2350     0.55    99.62
    27  |                             2     2352     0.08    99.70
    28  |                             0     2352     0.00    99.70
    29  |                             1     2353     0.04    99.75
    30  |                             0     2353     0.00    99.75
    31  |                             1     2354     0.04    99.79
    32  |                             1     2355     0.04    99.83
    33  |                             2     2357     0.08    99.92
    34  |                             0     2357     0.00    99.92
    35  |                             1     2358     0.04    99.96
    36  |                             1     2359     0.04   100.00
        -----+----+----+----+----+--
             5   10   15   20   25

              PERCENTAGE
```

Figure 29. Length-frequency histograms for *C. fluminea*, RM 284.0 and 287.2 combined, 1993

```
                          PERCENTAGE OF SHELLEN

SHELLEN                                                   CUM                CUM
                                                   FREQ   FREQ   PERCENT   PERCENT

    6  |                                              0      0      0.00      0.00
    7  |                                              0      0      0.00      0.00
    8  |                                              0      0      0.00      0.00
    9  |*                                             4      4      0.67      0.67
   10  |**                                           12     16      2.00      2.66
   11  |**                                           14     30      2.33      4.99
   12  |*                                             8     38      1.33      6.32
   13  |**                                           12     50      2.00      8.32
   14  |***                                          20     70      3.33     11.65
   15  |**                                           15     85      2.50     14.14
   16  |****                                         25    110      4.16     18.30
   17  |***                                          19    129      3.16     21.46
   18  |****                                         25    154      4.16     25.62
   19  |********                                     50    204      8.32     33.94
   20  |****************************                168    372     27.95     61.90
   21  |***************************                 163    535     27.12     89.02
   22  |*********                                    53    588      8.82     97.84
   23  |*                                             9    597      1.50     99.33
   24  |                                              1    598      0.17     99.50
   25  |                                              1    599      0.17     99.67
   26  |                                              0    599      0.00     99.67
   27  |                                              0    599      0.00     99.67
   28  |                                              0    599      0.00     99.67
   29  |                                              0    599      0.00     99.67
   30  |                                              0    599      0.00     99.67
   31  |                                              1    600      0.17     99.83
   32  |                                              0    600      0.00     99.83
   33  |                                              0    600      0.00     99.83
   34  |                                              1    601      0.17    100.00
   35  |                                              0    601      0.00    100.00
       -----+----+----+----+----+---
            5   10   15   20   25

               PERCENTAGE
```

Figure 30. Length-frequency histograms for *C. fluminea*, RM 289.9 and 292.0 combined, 1993

```
----------------------- SPECIES=ELLIPTIO CRASSIDENS -----------------------
                          PERCENTAGE OF SHELLEN

SHELLEN                                             CUM              CUM
                                             FREQ   FREQ  PERCENT  PERCENT

         |                                     0      0     0.00     0.00
   40    |                                     0      0     0.00     0.00
   42    |                                     0      0     0.00     0.00
   44    |                                     0      0     0.00     0.00
   46    |                                     0      0     0.00     0.00
   48    |                                     0      0     0.00     0.00
   50    |                                     0      0     0.00     0.00
   52    |****                                 1      1     2.00     2.00
   54    |                                     0      1     0.00     2.00
   56    |                                     0      1     0.00     2.00
   58    |                                     0      1     0.00     2.00
   60    |                                     0      1     0.00     2.00
   62    |                                     0      1     0.00     2.00
   64    |                                     0      1     0.00     2.00
   66    |                                     0      1     0.00     2.00
   68    |                                     0      1     0.00     2.00
   70    |                                     0      1     0.00     2.00
   72    |                                     0      1     0.00     2.00
   74    |                                     0      1     0.00     2.00
   76    |                                     0      1     0.00     2.00
   78    |                                     0      1     0.00     2.00
   80    |                                     0      1     0.00     2.00
   82    |                                     0      1     0.00     2.00
   84    |****                                 1      2     2.00     4.00
   86    |                                     0      2     0.00     4.00
   88    |****                                 1      3     2.00     6.00
   90    |****                                 1      4     2.00     8.00
   92    |****                                 1      5     2.00    10.00
   94    |****************                     4      9     8.00    18.00
   96    |************************             6     15    12.00    30.00
   98    |****************************         7     22    14.00    44.00
  100    |****************                     4     26     8.00    52.00
  102    |****************************         7     33    14.00    66.00
  104    |************                         3     36     6.00    72.00
  106    |********************                 5     41    10.00    82.00
  108    |************                         3     44     6.00    88.00
  110    |************                         3     47     6.00    94.00
  112    |****                                 1     48     2.00    96.00
  114    |****                                 1     49     2.00    98.00
  116    |                                     0     49     0.00    98.00
  118    |****                                 1     50     2.00   100.00
  120    |                                     0     50     0.00   100.00
         ----+---+---+---+---+---+---+
             2   4   6   8  10  12  14
                   PERCENTAGE
```

Figure 31. Length-frequency histogram for *E. crassidens* at RM 284.0, 287.2, 289.9, and 292.0, 1993

```
-------------------- SPECIES=QUADRULA PUSTULOSA --------------------

                    PERCENTAGE OF SHELLEN

SHELLEN                                      CUM              CUM
                                       FREQ  FREQ  PERCENT  PERCENT
   10  |                                  0     0     0.00     0.00
   12  |                                  0     0     0.00     0.00
   14  |                                  0     0     0.00     0.00
   16  |                                  0     0     0.00     0.00
   18  |***                               1     1     1.39     1.39
   20  |***                               1     2     1.39     2.78
   22  |                                  0     2     0.00     2.78
   24  |***                               1     3     1.39     4.17
   26  |***                               1     4     1.39     5.56
   28  |***                               1     5     1.39     6.94
   30  |********                          3     8     4.17    11.11
   32  |********                          3    11     4.17    15.28
   34  |***                               1    12     1.39    16.67
   36  |******                            2    14     2.78    19.44
   38  |******                            2    16     2.78    22.22
   40  |***                               1    17     1.39    23.61
   42  |                                  0    17     0.00    23.61
   44  |***                               1    18     1.39    25.00
   46  |                                  0    18     0.00    25.00
   48  |*************************         9    27    12.50    37.50
   50  |******                            2    29     2.78    40.28
   52  |**********************            8    37    11.11    51.39
   54  |******************************   11    48    15.28    66.67
   56  |**********************            8    56    11.11    77.78
   58  |*****************                 6    62     8.33    86.11
   60  |*****************                 6    68     8.33    94.44
   62  |***                               1    69     1.39    95.83
   64  |***                               1    70     1.39    97.22
   66  |***                               1    71     1.39    98.61
   68  |***                               1    72     1.39   100.00
   70  |                                  0    72     0.00   100.00
   72  |                                  0    72     0.00   100.00
   74  |                                  0    72     0.00   100.00
   76  |                                  0    72     0.00   100.00
   78  |                                  0    72     0.00   100.00
   80  |                                  0    72     0.00   100.00
       ----+---+---+---+---+---+---+---
           2   4   6   8  10  12  14

              PERCENTAGE
```

Figure 32. Length-frequency histogram for *Q. p. pustulosa* collected at RM 284.0, 287.2, 289.9, and 292.0, 1993

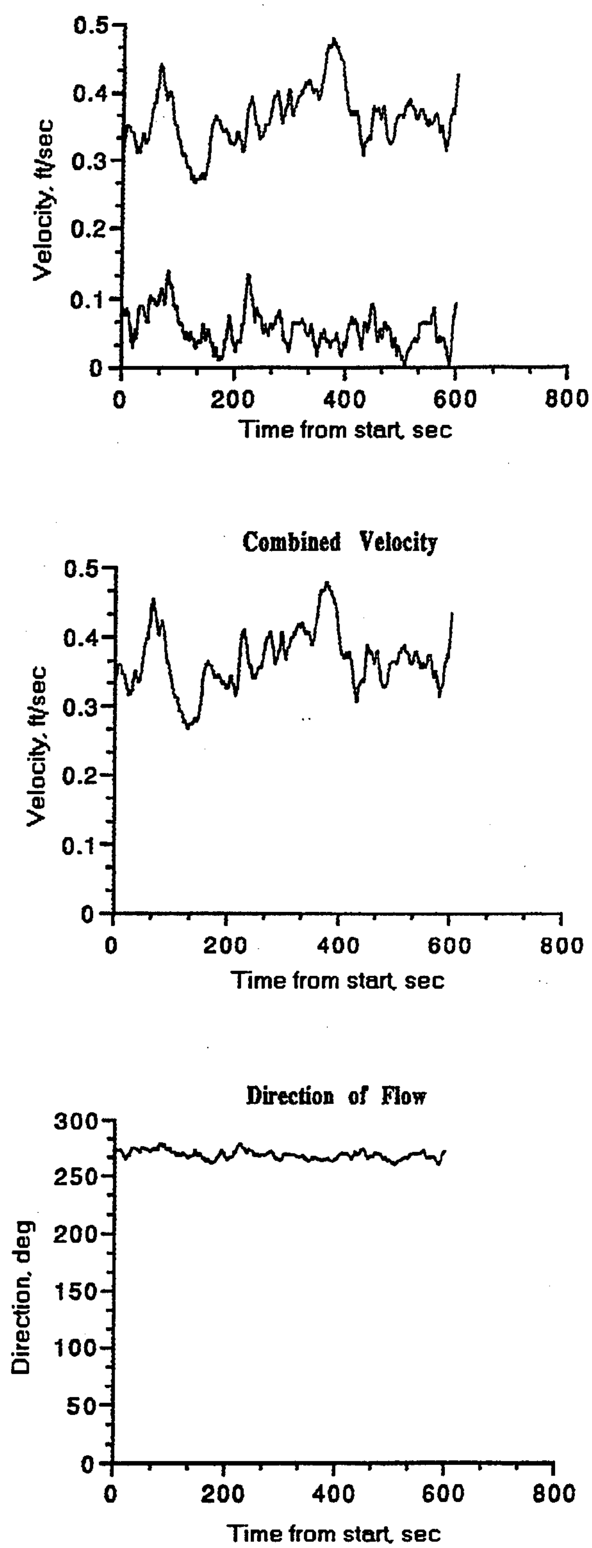


Figure 33. Individual velocity components, combined velocity, and direction of flow for ambient river conditions, July 1993 (Test No. 1)

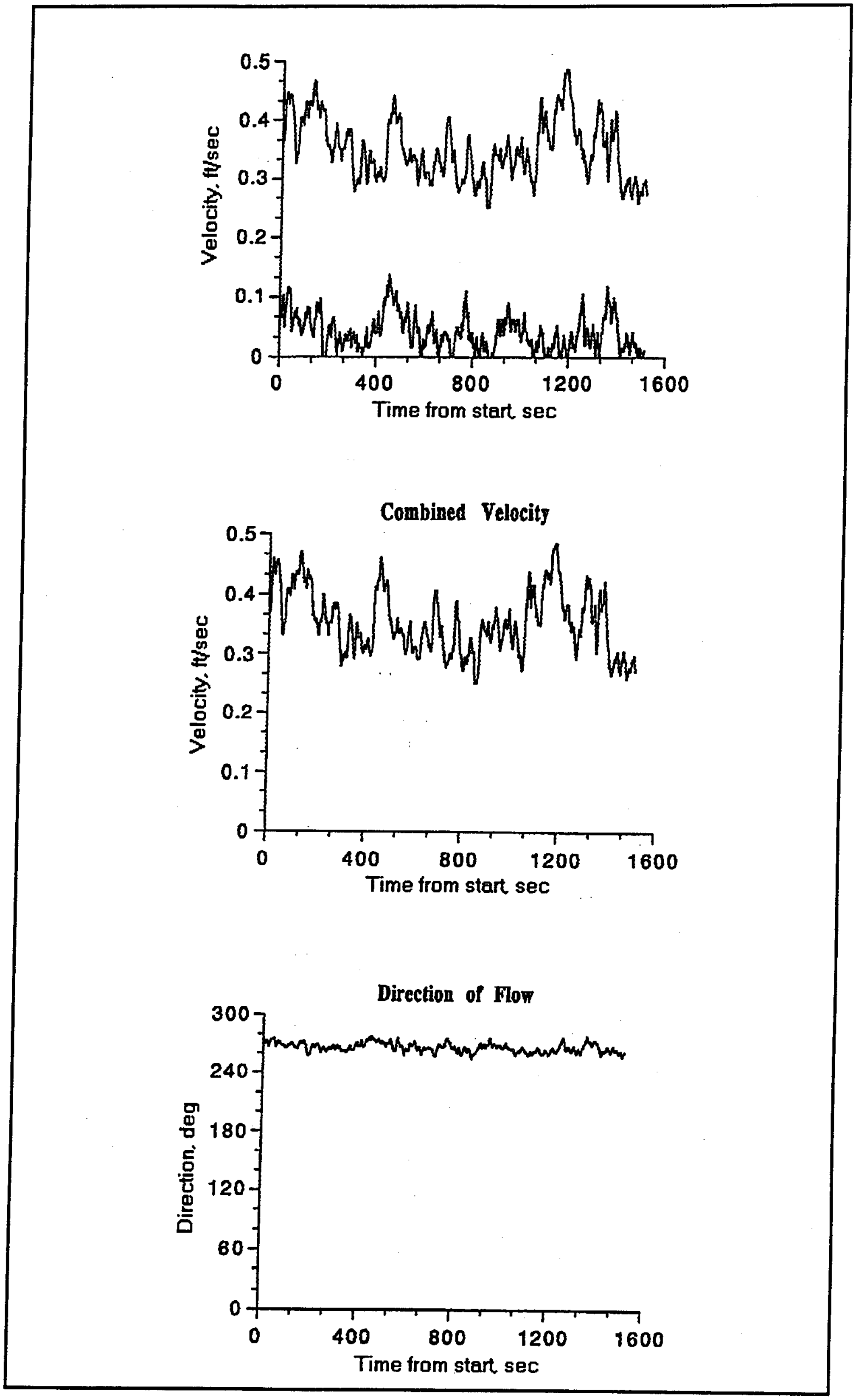


Figure 34. Individual velocity components, combined velocity, and direction of flow for ambient river conditions, July 1993 (Test No. 2)

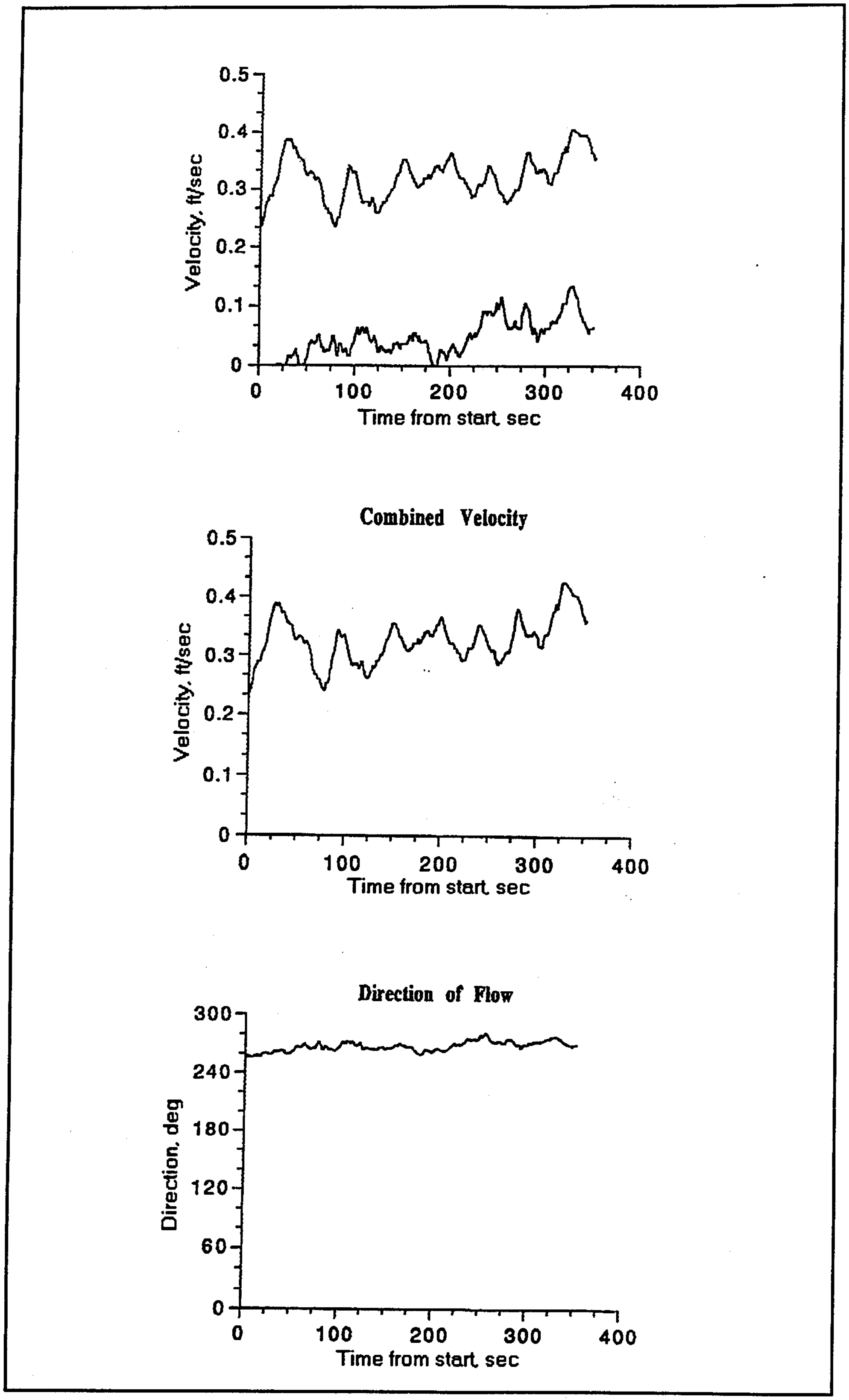


Figure 35. Individual velocity components, combined velocity, and direction of flow for ambient river conditions, July 1993 (Test No. 3)

Table 13
Summary Statistics for Water Velocity Data (ft/sec) Collected in the Upper Ohio River Near Huntington, WV, July 1993 (See Figures 33-36)

Statistic	Y	X	Combined Velocity	Flow Direction
File: HDATA1.WK1; Test #1; Seconds: 50-249				
Mean	0.341	0.066	0.348	270.856
SD	0.043	0.033	0.047	4.361
Min	0.266	0.010	0.268	261.800
Max	0.442	0.139	0.455	279.500
Range	0.176	0.129	0.187	17.700
N	200	200	200	200
File HDATA2.WK1; Test #2; Seconds: 50-249				
Mean	0.392	0.051	0.396	267.363
SD	0.038	0.025	0.039	3.458
Min	0.327	-0.017	0.333	257.400
Max	0.468	0.098	0.472	273.400
Range	0.141	0.115	0.139	16.000
N	200	200	200	200
File HDATA3.WK1; Test #3; Seconds: 50-249				
Mean	0.309	0.040	0.312	267.500
SD	0.029	0.021	0.029	3.772
Min	0.236	-0.003	0.241	259.600
Max	0.365	0.106	0.366	279.600
Range	0.129	0.109	0.125	20.000
N	200	200	200	200
File HDATA4.WK1; Test #4; During Test; Seconds: 186-385				
Mean	0.259	0.036	0.263	268.163
SD	0.059	0.030	0.059	7.099
Min	0.129	-0.023	0.130	255.100
Max	0.365	0.093	0.374	290.800
Range	0.236	0.116	0.244	35.700
N	200	200	200	200
File HDATA4.WK1; Test #4; After Test; Seconds: 650-849				
Mean	0.341	0.023	0.343	263.732
SD	0.036	0.020	0.036	3.462
Min	0.272	-0.023	0.272	255.400
Max	0.398	0.066	0.399	271.700
Range	0.126	0.089	0.127	16.300
N	200	200	200	200

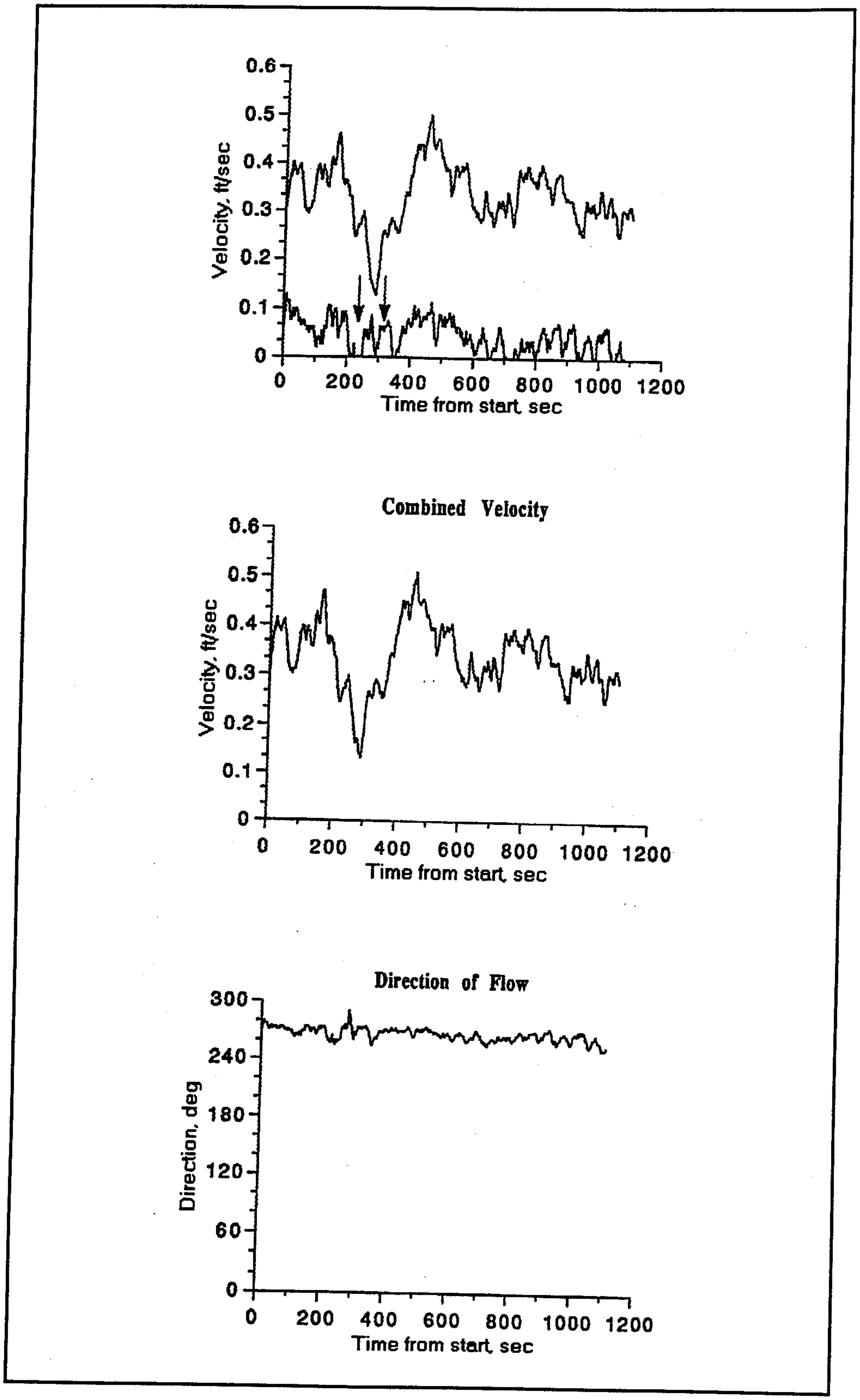


Figure 36. Individual velocity components, combined velocity, and direction of flow for downward passage of a commercial navigation vessel, July 1993 (Test No. 4)

4 Discussion

Community Characteristics

No major differences in mussel community composition were noted between the present study year (1993) and 1992. The fauna in the reach of the UOR consisted almost entirely of thick-shelled species such as *E. crassidens, Q. p. pustulosa,* with lesser numbers of *Q. metanevra* and *P. cordatum.* Thin-shelled species such as *Anodonta* spp. and *L. fragilis* were either absent or very uncommon. Within their range these thin-shelled species are found in appropriate substratum in large rivers (Murray and Leonard 1962, Parmalee 1967, and Starrett 1971). Each has multiple fish hosts (Fuller 1974) and would be more common in this reach if more suitable substratum and flow for molluscs existed. It is possible that young are often frequently recruited at these bars. However, the erosive action of high discharge and the coarse substratum probably kill immatures before they reach adult size.

A single specimen of *Lampsilis abrupta* (Say, 1831), listed as endangered by the U.S. Fish and Wildlife Service (1991), was collected during qualitative searches by divers at RM 287.2 (Table 3). This species has been reported from this reach of the UOR (Tolin et al. 1987); however, it is so uncommon that it is likely to be missed even during intensive surveys. This species comprised 0.02 percent of the qualitative collection (one individual out of 4,700 specimens). Combining the total number of quantitative (0.25 sq m) samples collected in 1992 (120) and 1993 (118) yields 238 total quadrats or 59.5 sq m of area sampled. Density of *L. abrupta* must be less than 0.0168/sq m (less than 1 individual per 60 sq m). It should be noted that even at extremely low densities (1/100 sq m) there could be many tens of *L. abrupta* in this river reach.

It is not unusual for endangered species to be extremely uncommon (although collectable) at large river mussel beds. In 1992 a single endangered *Plethobasus cooperianus* was found in a collection of 1,150 individuals taken at a mussel bed in the lower Ohio River (Payne and Miller 1993). In a survey of the lower Tennessee River, Miller, Payne, and Tippitt (1992) estimated that the least common species in the collection was approximately 0.0252 individuals/sq m.

Another uncommon species of some concern is *Plethobasus cyphyus* (Rafinesque, 1820), listed as endangered by the Commonwealth of Kentucky (Branson et al. 1981), which was collected using qualitative and quantitative techniques. This species has been found in a dense and diverse bed in the lower Ohio River near Olmsted, IL (Payne and Miller 1983), and comprised 0.19 percent of the fauna at a site stabilized by wing dams in Pool 10 of the upper Mississippi River (Miller 1988).

Total species richness in the study area (25 species based on quantitative and qualitative methods, Table 2) is similar to that at other mussel beds in large rivers. At a mussel bed in the lower Ohio River near Olmsted, IL, 26 species of freshwater mussels were collected using qualitative and quantitative methods (Miller, Payne, and Siemsen 1986). In a survey of the lower Tennessee River, Miller and Payne (1992) collected 4,768 individuals and identified 23 species.

Total density

Mean unionid density at the four locations in the UOR (3.6 to 13.4 individuals/sq m, Table 8) is similar to data obtained at three locations in the 1992 survey (7.9 to 13.7 individuals/sq m). These density data are slightly less than values often found at large river mussel beds. In the lower Tennessee River, Miller, Payne, and Tippit (1992) estimated total density to range from 9.2 to 128.0 individuals/sq m at six closely placed sites (10 quadrats collected at each). In a survey of the upper Mississippi River, Miller et al. (1990) reported that total mussel density ranged from 5.2 to 333.2 individuals/sq m at 16 sites (10 quantitative samples were taken at each). At half of those sites total density was greater than 50 individuals/sq m, and at four sites it was greater than 100 individuals/sq m. At an inshore and offshore site sampled in 1986 at RM 18.6 in the lower Tennessee River (32 quantitative samples were collected at each), total mussel density was 187.7 and 79.7 individuals/sq m, respectively (Way, Miller, and Payne 1989).

Changes in water velocity associated with vessel passage

Previous navigation traffic studies conducted in the upper Mississippi River have shown that upbound and downbound passages have distinctly different effects on water velocity (Miller and Payne 1992). Upbound passages have little effect on minimum velocity; however, the return flow caused by displacement of water from the hull tends to increase the maximum velocity. The reverse is true for downbound passages. Maximum velocity is not noticeably affected, but the return flow caused by vessel passage tends to reduce minimum velocity. The range and standard deviation for velocity readings are usually greater during vessel passage than under ambient conditions. However, the magnitude of this change, usually only several tenths of a foot per second, is typically not sufficient to disrupt the substratum (Figure 36). Typically, events caused by vessel

passage last no more than 50 sec. Effects of vessel passage on the water velocity near the substratum-water interface are measurable, although probably not of a sufficient magnitude to affect benthic organisms.

Size demography of dominant bivalve populations

The size demography of *E. crassidens* was similar in 1993 and 1992 (see Payne and Miller (1994) for 1992 data). In both years the *E. crassidens* population was comprised of old, large individuals. However, the 53-mm-long individual collected in 1993 indicates the possibility of at least some occasional recruitment of this species. *Elliptio crassidens* relies on the skipjack herring, *Alosa chrysochloris*, as the host fish for its glochidia (Fuller 1974). High lift dams prevent annual upstream migrations that are made by this fish species (Fuller 1974). Ten such dams, constructed during this century, occur between these study sites near Huntington, WV, and the confluence of the Ohio River with the Mississippi River. It is likely that numbers of this species in the Ohio River have declined as a result of reduction of skipjack herring due to dam construction. An examination of historical data from the upper Mississippi River indicates that the abundance of *E. crassidens* has declined in the upper Mississippi River, presumably because of dam construction (Havlik and Marking 1980).

Demography of *Q. p. pustulosa* was virtually identical in 1993 and 1992. This species, which utilizes some relatively common fish hosts (the black and brown bullhead, channel and flathead catfish, and white crappie) (Fuller 1974), has consistently shown substantial recent recruitment. Comparison of population demography of *E. crassidens* and *Q. p. pustulosa* suggests that hydrologic and water quality conditions at these sites appear to be suitable for mussel recruitment. Fish host availability could limit recruitment of some species.

Size demography of *C. fluminea* differs greatly at RM 284.0 and 287.7 versus RM 289.9 and 292.0. The upriver sites support many more large and fewer small *C. fluminea* than the downriver sites. There is an indication that substratum characteristics are associated with these differences. The downriver sites at this location tend to have less sand and fine gravel than upstream sites. Slightly more depositional conditions upriver seem appropriate in relation to the lower overall density of *C. fluminea* but not with respect to slightly lower density of small individuals. In addition to substratum effects on *C. fluminea*, the greater density of small individuals at downstream sites may reflect intraspecific, intercohort competition. It is possible that the low density of large *C. fluminea* at the downstream sites enhances recruitment whereas erosional conditions reduce recruitment.

Nonindigenous species

There was a significant positive correlation between density and biomass of *C. fluminea* and percentage of medium and fine-grained sediments (particle size less than 34 mm, Table 11). Conversely, the correlation between biomass and density of *C. fluminea* and particle sizes greater than 34.0 mm was negative. Asian clams were more common in fine-grained than in cobble-sized sediments. None of the correlations between density of Unionidae versus particle sizes were significant ($p > 0.05$). Significant correlations ($p < 0.01$) were found for Unionidae biomass and the two largest sizes classes of sediments (12.7-34.0 mm, and >34.0 mm). Biomass of Unionidae was not significantly related to percentage of sediments <12.7 mm. There were also significant negative relationships between biomass of Unionidae and *C. fluminea* (Table 11). This relationship was the result of having Asian clams negatively related to large-sized particles, and Unionidae positively related to large-sized particles. It appears that grain size indirectly affected the relationship between Unionidae and *C. fluminea*.

The zebra mussel, *Dreissena polymorpha*, has now become part of the bivalve fauna throughout the Mississippi River (from Wisconsin to New Orleans) and much of the Ohio River downriver of Pittsburgh. In the fall of 1992, a single *D. polymorpha* was found attached to a piece of gravel at a mussel bed in the lower Ohio River. In the fall of 1993, zebra mussels were found in virtually every quantitative sample at that bed, and densities were as high as 200/sq m. Only eight zebra mussels were found during the present survey of the UOR, and all were located at RM 292.0 in the quantitative samples. The estimated density was 1.6/sq m. It is likely that rapid increases in density will be observed by the summer of 1994. *Dreissena polymorpha*, unlike *C. fluminea*, can bysally attach to unionids in high numbers. Therefore, there is potentially much more direct competition between zebra mussels and native mussels than between this group and Asian clams.

Changes in water quality in the Ohio River near Huntington

Suitable conditions of temperature, water velocity, and substratum currently exist in this reach of the Ohio River for freshwater mussels. The comparatively low densities could be the result of past conditions of poor water quality. An examination of selected water quality parameters (specific conductance, pH, and dissolved oxygen) from 1961 to the late 1980's in this reach of the river illustrates that conditions are gradually improving (Figures 37 and 38). Specific conductance, a measure of all cations and anions in water, is gradually decreasing, which could indicate that point and nonpoint source pollution (a source of ions which affect water quality) has declined gradually. Dissolved oxygen and pH have also increased slightly, a further indication of improved conditions.

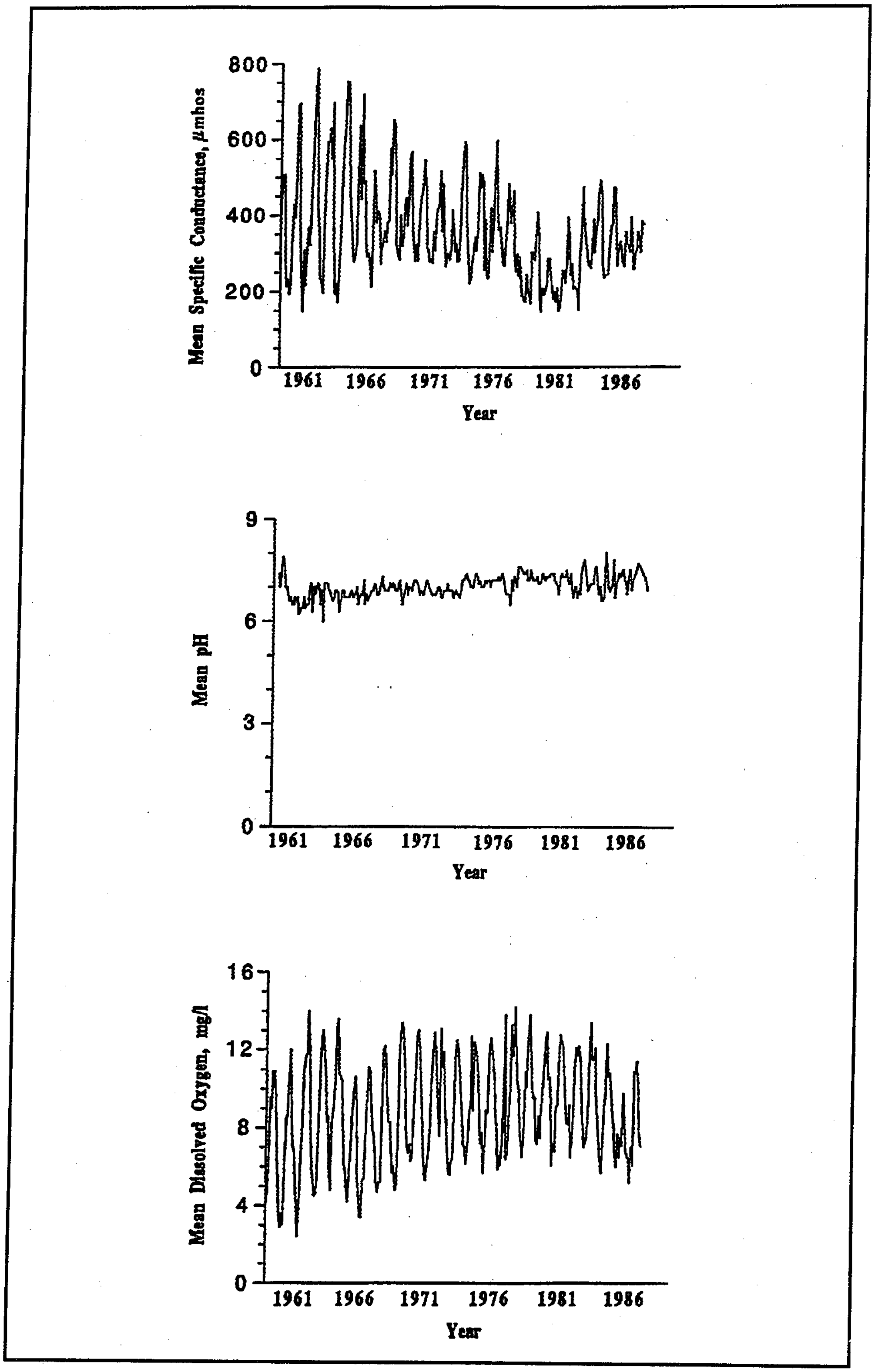


Figure 37. Monthly means for specific conductance, pH, and dissolved oxygen, Ohio River at Huntington, 1961-88. Data collected by the Ohio River Sanitation Commission, Cincinnati, Ohio, and retrieved through STORET, an automated data storage and retrieval system

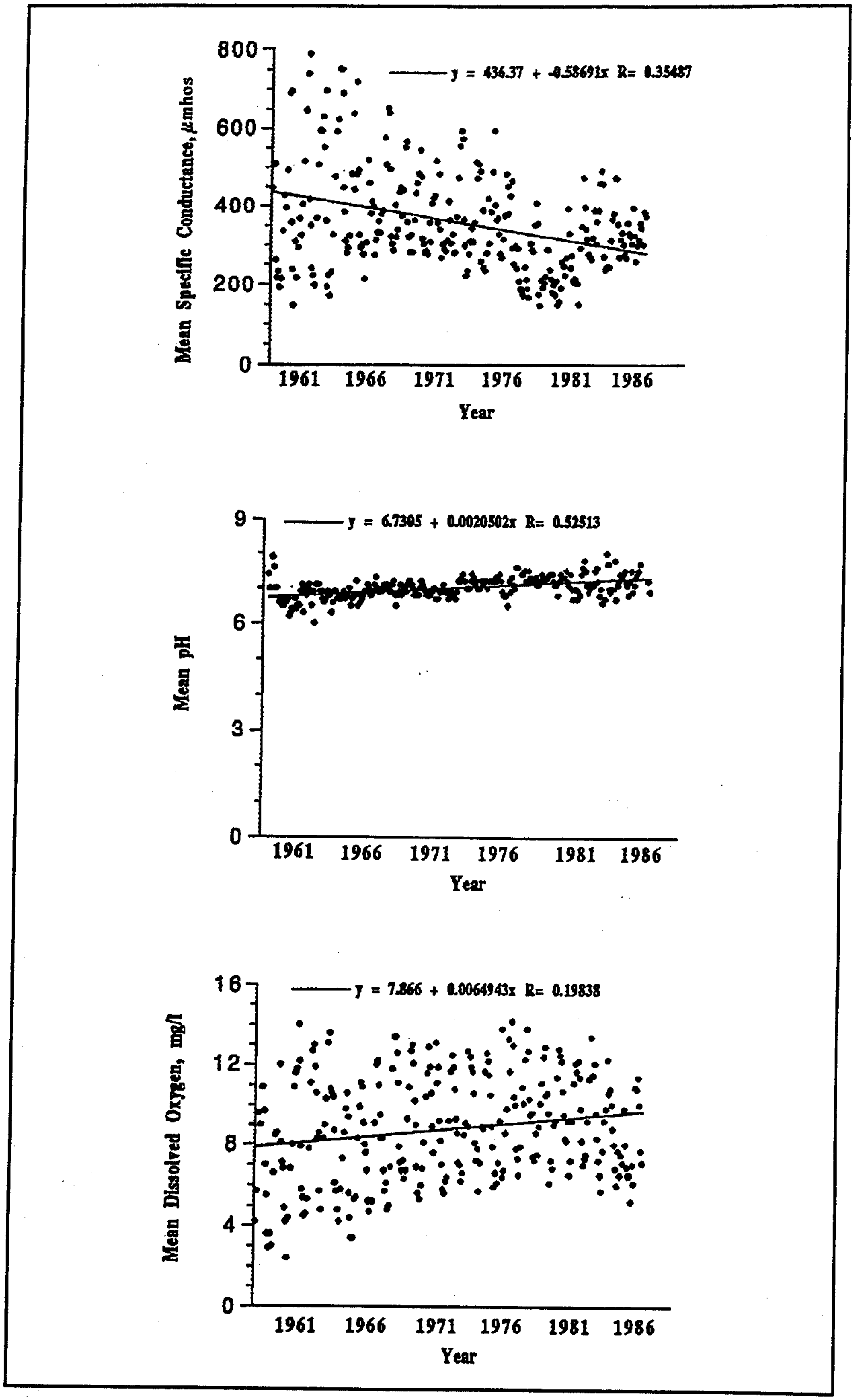


Figure 38. Relationship between collection data and monthly means for specific conductance, pH, and dissolved oxygen, Ohio River at Huntington, 1961-88 (data from Storet)

Based on results obtained in 1992 and 1993, conditions at these mussel beds appear to have remained stable in this reach of the Ohio River. The continued presence of some (although limited) recruitment for *Q. p. pustulosa* indicates that conditions exist for other species to successfully recruit. Continued monitoring of mussel resources in this river reach could provide additional information that depicts a gradually improving community that parallels improved conditions in water quality.

Summary

The continued use of inland waterways to transport bulk commodities (Dietz et al. 1983) has caused planners and biologists in government agencies to express concern over the possible negative effects of commercial use of waterways on freshwater mussels (Rasmussen 1983). Rather than rely on speculation or questionable predictive methods, quantitative and qualitative techniques should be used to obtain data on mussel density, relative species abundance, community composition, and population demography. These parameters provide the most useful measures of the overall health and ultimate survival of a mussel community. They provide an opportunity to investigate the effects of complex, episodic events on a resource with ecological, economic, and cultural value. The use of sustained research has been considered by Franklin (1987) to be a critical need. These data can be used to evaluate the impacts of man-made and natural disturbances. The results of future studies at these mussel beds will provide information necessary to evaluate the effects of commercial navigation vessels and other water resource development on freshwater molluscs in this reach of the UOR.

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13. ABSTRACT *(Maximum 200 words)*

A survey to assess community characteristics, density, population demography of dominant species, and the likelihood of finding endangered species of freshwater mussels (Unionidae) was conducted in the upper Ohio River (approximate River Miles (RM) 292 to 284) near Huntington, WV, in July 1993. Data were used to analyze impacts of commercial navigation traffic resulting from increased barge traffic on the Ohio River due to projected increases in economic activities. Data collected in 1993 are compared with results collected in October 1992, the first year of this project.

A total of 4,700 individuals and 24 species of mussels were collected in the study area using qualitative methods. The fauna was dominated by two thick-shelled species, *Elliptio crassidens* (54.7 percent) and *Quadrula pustulosa pustulosa* (18.3 percent). Only eight zebra mussels (*Dreissena polymorpha*) were collected at a bed located at RM 292 (estimated density = 1.6/sq m) although this species was found at Robert C. Byrd Lock and Dam immediately upriver (RM 279.2). Total density (individuals per square meter) of Unionidae at four beds ranged from 3.6 (± 0.7 standard error of the mean) to 13.4 (± 2.0). Total density of the Asian clam, *Corbicula fluminea*, ranged from 65.6 (± 7.1) to 821.1 (± 104.2). Based on quantitative sampling, species diversity and evenness were moderate and ranged from 1.60 to 1.86 and 0.67 to 0.96. Evidence of recent recruitment for most species was low; 3.7 percent of the individuals and 18.7 percent of the species were less than 30 mm in total shell length.

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Analysis of historical data on specific conductance, pH, and dissolved oxygen in this reach of the river indicates that water quality is gradually improving. Results of these studies will provide information that can be used to evaluate effects of improving water quality, as well as the environmental effects of commercial navigation traffic, planned water resource developments, unexpected industrial accidents, or introduction and spread of zebra mussels, on native species.